COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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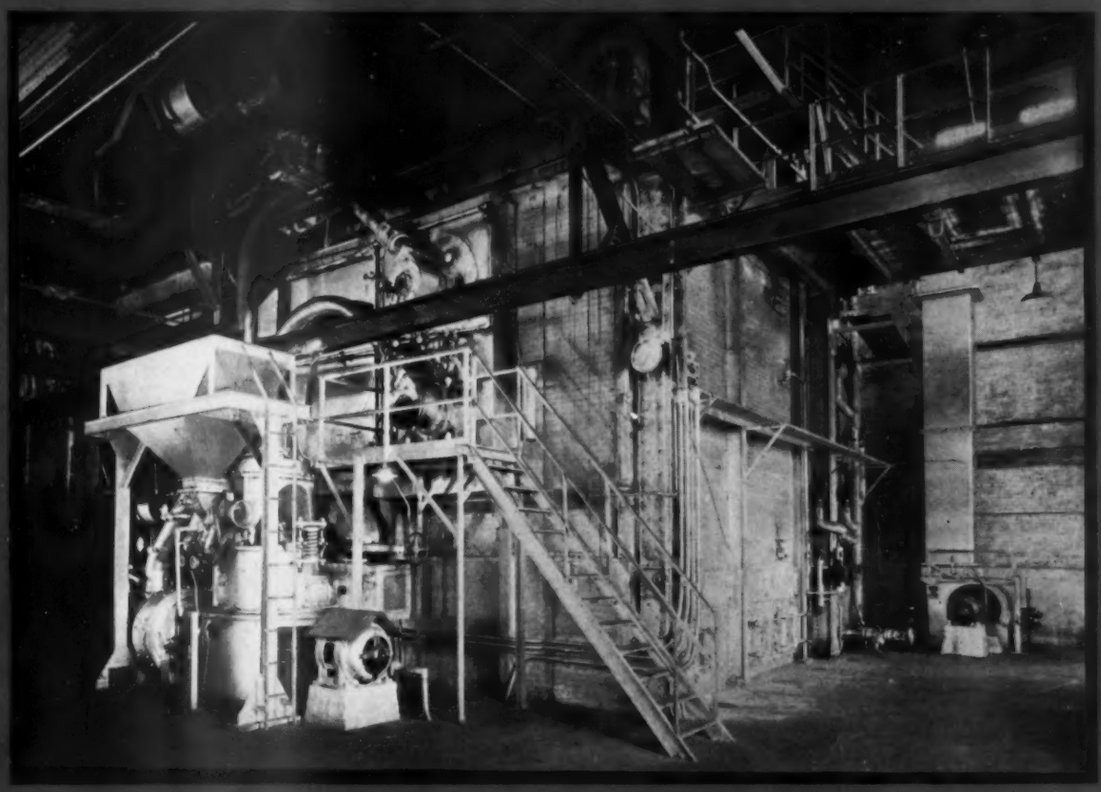

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Factors Influencing Selection of Steam Generating Equipment

Removal of Silica from Industrial Boiler-Water Supplies

Modernizing Settings of Traveling Grate Stokers

Fuel Oil Burning

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COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME TWELVE NUMBER FIVE

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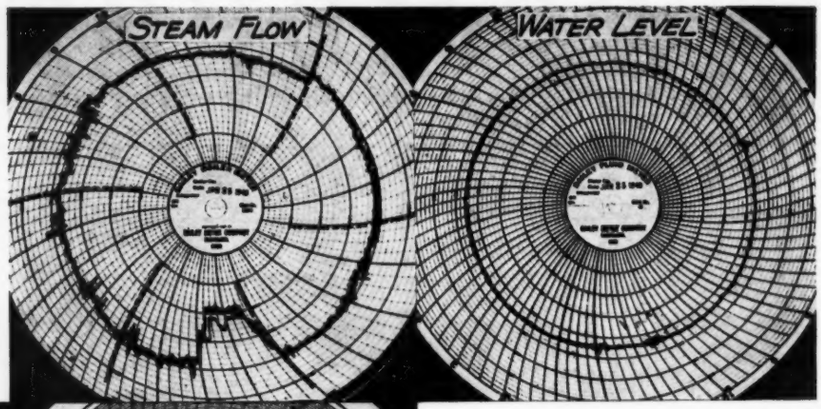

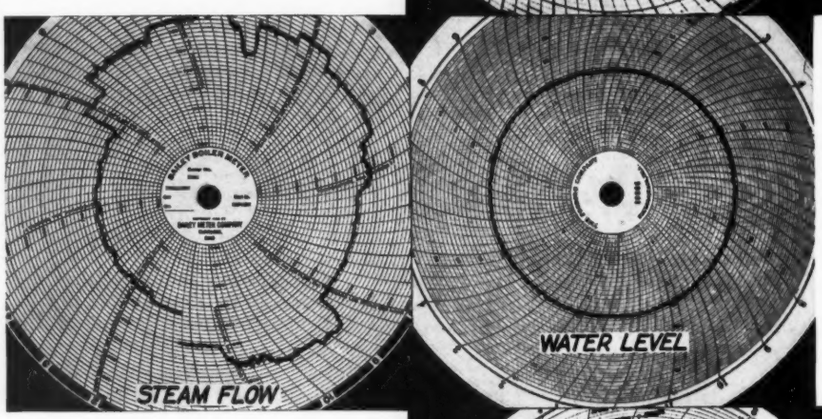

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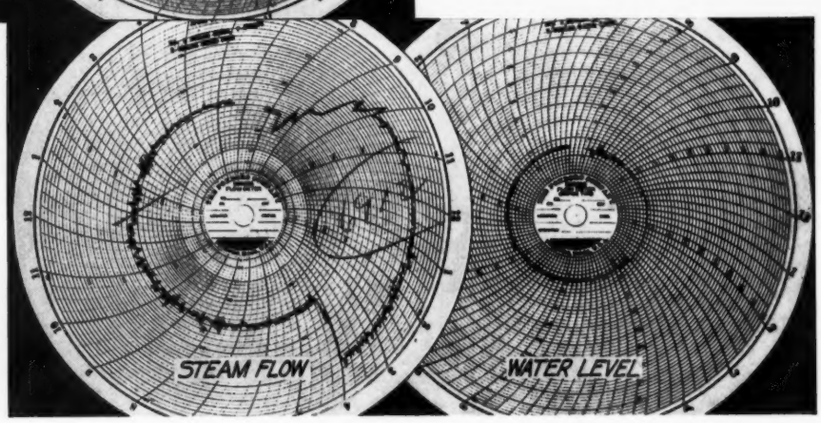

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EDITORIAL

1940 Power Show

The Fourteenth National Exposition of Power and Mechanical Engineering will be held at the Grand Central Palace, New York, on December 2 to 7. As in former years, this biennial event will be concurrent with the Annual Meeting of the American Society of Mechanical Engineers.

A perusal of the list of exhibits indicates that while there will be few steam generating units and prime movers, other power plant equipment from coal pile to switchboard will be well represented. Of particular interest should be the exhibits of piping and valves, in view of recent advances in steam conditions and the consequent development work of such manufacturers in the field of high pressures and high steam temperatures. Similarly, instrumentation and control devices will occupy a prominent place, depicting many refinements in precision and in the safeguarding of economy. Air conditioning and refrigeration also will be accorded a prominent place by reason of the fact that these services are an integral part of the power load in many places.

In these times of rapid advances in power plant practice every two years is none too often to show the improvements in much of the component power equipment and it is believed that the present activity in the field should result in worth-while attendance, notwithstanding the fact that duties incident to the defense program may deter some who otherwise would attend.

Influence of Experience and Research on Design of Large Units

Despite the present good availability and excellent performance records of most high-capacity steam generating units, experience gained over the last four or five years has taught both designers and operators many things they did not previously recognize as accompaniments of the rapid advances in operating practice during this period. The knowledge gained is now being incorporated in the latest units and should make for still better performance.

Researches on heat absorption, on ash-fusion temperatures under actual furnace conditions, developments in burners and studies of circulation have all fortified the designer better to meet these problems as incurred by present conditions.

It is quite apparent that some manufacturers who previously advocated very high furnace heat releases have lately fallen in line with, or in some cases even below, those who consistently employed moderate values of heat release. This can be verified by plotting the Btu heat release per unit of furnace volume for units installed from 1935 to 1940.

Another modification resulting from experience over this period has been the general increase in the spacing of superheater tubes, where high-duty service and high-ash coals are involved, and the lowering of entrance gas velocities in order better to combat the slagging problems. Operators have also learned that instead of carrying full load continuously twenty-four hours a day, seven days a week, the slagging problem is made easier by decreasing the load on such units for an hour or two each night.

There is a trend toward increased furnace widths, where not restricted by existing building steelwork, the employment of more liberal drum capacities, and more extensive use of high-grade alloy steels for those parts subject to the most severe service. The costs which these involved were limiting factors during the highly competitive period existing a few years ago when many purchasers were accustomed to let price outweigh other considerations.

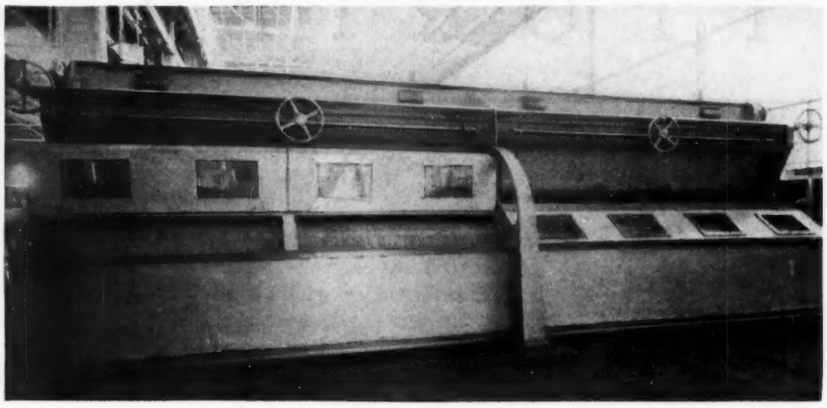
As a result of accumulated data and experience, present designs of steam generating units are more exact than those of ten to fifteen years ago when it was customary to expect outputs far in excess of rated capacities. Notwithstanding this, there are indications of a trend toward more conservatism than was apparent four or five years ago in order to allow for the unanticipated operating factors.

St. Lawrence Power Advances

The proposed St. Lawrence power and waterway development, which has long been a subject of controversy, advanced a step nearer reality when the President recently allocated a million dollars to the Federal Power Commission and the Army Engineers for borings and preliminary surveys.

It will be recalled that Canada previously had been adverse to this project because of its share of the expenditure involved and the fact that it already had ample power, but since the start of the present war it has become receptive to the idea. Now, with the election in this country over and the majority in the new Congress subservient to the President's wishes, it is anticipated that the project will be pushed under the guise that it is necessary to national defense.

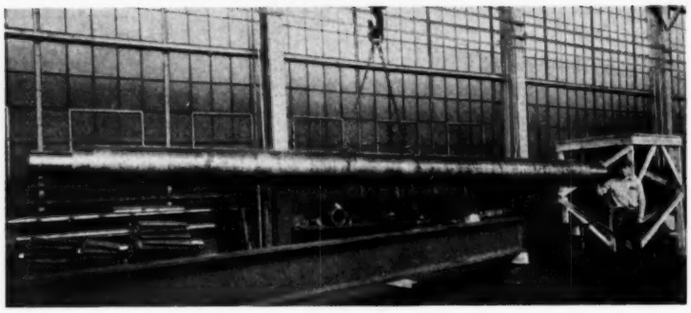
However, when one considers the probable time involved before power would be available from this development, it is far-fetched to assume that it would be able to play a part in the present defense program. Instead, it must be classed with other federal water power projects now in various stages of construction, and its economic justification compared with power generation by steam will continue to remain a controversial question among engineers.



Left—Stoker front showing hopper and hood

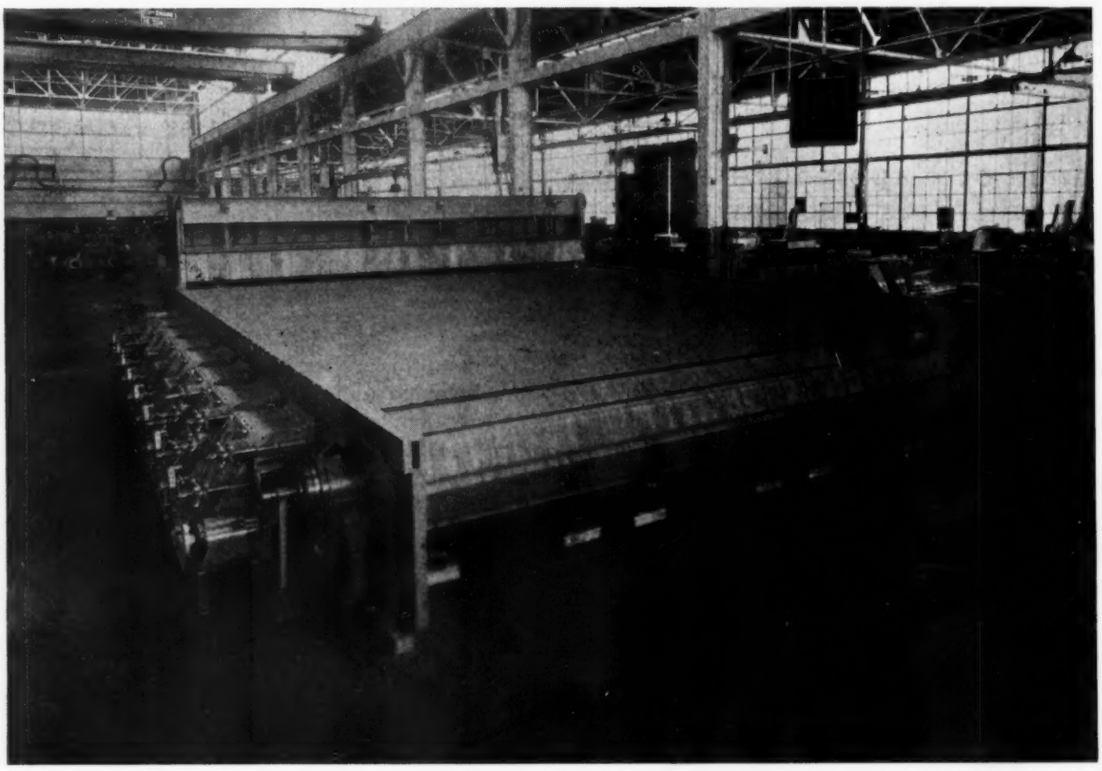
Giant Stokers

One of two Coxe traveling grate stokers for the Cedar Plant of the Pennsylvania Power & Light Company at Harrisburg. Each is 23 ft. wide by 25½ ft long and will burn river anthracite or No. 4 buckwheat under a 185,000-lb per hr high-pressure boiler.



Upper View—Drive Shaft

Lower View—Stoker assembled in shop



Factors Influencing Selection of Steam Generating Equipment

By L. J. MARSHALL

Combustion Engineering Co., Inc.

Failure to state where the specified steam pressure is to apply, the range of load over which steam temperature is to remain constant, or to give accurate information as to fuel analysis and grindability often makes it difficult to analyze inquiries properly. These points are discussed as well as the principal factors entering into the selection and design of steam generating equipment.

IN ORDER that inquiries for steam generating equipment may be properly analyzed and the correct selection made it is important that they be accompanied by certain essential information.

Steam Pressure

Among the items concerning which there is often misunderstanding is steam pressure. Frequently, inquiries mention capacity and pressure, without any explanation concerning the latter. There is no indication whether the specified pressure applies to that at the boiler drum, at the superheater outlet, at the turbine throttle, or the design pressure of the boiler. It is desirable that the pressure be stated as at the superheater outlet or at the boiler drum, if no superheater is to be employed. If a customer cannot determine the exact pressure at the superheater outlet, enough information should be given to permit a determination of the pressure drop between the boiler and the turbine.

Within the past year safety valve manufacturers have advised that they will not guarantee valves to operate within three per cent of the set pressure, as was the custom previously. Because of this, an allowance of three per cent should be provided in addition to the pressure drop through the superheater. For example, assume that a pressure of 480 lb is required at the superheater outlet and the pressure drop through the superheater is 20 lb. If the superheater outlet pressure is 480 lb, the pressure of the steam leaving the drum or entering the superheater will be 500 lb. The safety valve allowance, namely, three per cent of 500 lb, or 15 lb, gives a minimum design pressure of 480 + 20 + 15 = 515 lb. According to standards of the American Boiler Manufacturers' Association, the standard pressure nearest to this figure is 525 lb.

Some years ago it was customary to provide sufficient leeway to cover the blowdown of the safety valves of two to four per cent, as specified by the A.S.M.E. Power Test Codes. This blowdown added to the superheater pressure drop gave the minimum design pressure. The specified design pressure was that allowed for the necessary thickness of the boiler tubes. Drums and all other pressure parts were designed for the same pressure as the tubes. The present method gives approximately the same leeway as the former method, except that design pressures are now given in increments of 25 lb above 200 lb and in increments of 20 lb below 200 lb.

Some manufacturers, because of competitive situations, have allowed practically no leeway between drum operating pressure and design pressure. This is not to be recommended, for the safety valves will blow if the pressure reaches the setting of the valves corresponding to the design pressure, and the pressure at the boiler will be reduced by the amount of blowdown of the valves; hence the desired pressure cannot be realized until the valves have seated.

Steam Temperature

A second item that often causes considerable confusion is steam temperature and the range of load over which a constant temperature is desired.

The control feature is seldom involved on small units, but it is essential that the total steam temperature or the degrees of superheat be specified at one rating only. Frequently it will be found that reference to steam temperature in one section of a specification will not correspond to that stated in another section.

In practically all installations involving total steam temperatures above 800 F, some degree of control is desired. Before the design of a unit can be determined, the minimum evaporation point at which the stated steam temperature is desired must be known. Not only is the superheater affected by changing this point, but the size and design of furnace and boiler is also involved, as well as the type and arrangement of burners if the unit be fired by the pulverized coal, oil or gas. Operating engineers and turbine manufacturers sometimes specify ranges that are impracticable to meet, as very wide load ranges for constant steam temperature may mean increased costs that cannot be justified.

Fuel Analysis and Grindability

Another item that is often bothersome, particularly in connection with the selection of pulverizers, is the fuel analysis and its grindability. There have been instances where mills larger than those actually required have been indicated by incorrect preliminary information on grindability and moisture. The pulverizer is selected to handle a given quantity of coal with maximum moisture content. If the moisture content is higher than that indicated, the output will be reduced, and it will be reduced still further if the temperature of the air to the mill is lower than anticipated. However, with the correct fuel data given, the unit can be designed to give the required air temperature for mill drying and the

proper size pulverizer selected for the maximum moisture conditions.

Selection of Equipment

Among the factors that influence the selection of equipment are customer's preference, space conditions, capacity and steam conditions, fuel characteristics and cost.

Often the customer's preference for a particular type of equipment determines its design, to a large extent. Obviously, it is to the mutual advantage of customer and manufacturer when a satisfactory installation results from cooperative efforts on the part of both. Suggestions from a customer's engineers for improvement in design should be welcomed and given full consideration; and if not followed, it should be only because the manufacturer, in view of his experience, can suggest more satisfactory, or perhaps less expensive designs that will accomplish the desired results.

As regards space limitations, if the available space is limited in depth from front to rear, but relatively high, the type of unit dictated will not be the same as if the headroom were limited but the front to rear dimension relatively large. A long narrow stoker may be employed in one installation whereas a short wide one may be necessary in another for exactly the same steam conditions. If the space from front to rear is small but the headroom large, a pulverized coal furnace under a horizontal boiler might make a satisfactory arrangement, whereas for the same output and steam conditions a two-drum unit with furnace located in front would fit reverse conditions.

Pulverized Coal vs. Stokers

For capacities below 35,000 lb of steam per hour pulverized coal, in general, is not as desirable as stokers. With such outputs stokers of the single-retort, spreader or traveling-grate types are most applicable. Above 35,000 lb per hr the single-retort stoker gives place to the multiple-retort or traveling grate designs. Spreader stokers may be used for evaporations as high as 120,000 lb per hr.

If conditions are such as to indicate a stoker installation to be most desirable, a multiple-report type would be used if a good grade of eastern bituminous coal is available, whereas a stoker of the chain-grate type would be ordinarily selected if the coal is of the mid-western variety. A traveling-grate stoker of the bar and key type would, of course, be employed for anthracite, lignite and coke breeze. For smaller capacities the single-retort underfeed stoker has also been employed successfully for anthracite as well as bituminous coal.

Pulverized coal furnaces can be made smaller for burning high-grade, high-ash-fusion temperature coals than when burning the poor grades of low-ash-fusion temperature coals. The design and location of superheater as well as the arrangement of boiler surfaces are also affected by the type and quality of the fuel, as is also the type of air heater. A plate-type air heater would ordinarily not be recommended for oil or high-sulphur coals because of the possibility of corrosion and inconvenience, and the consequent expense of replacement of plates.

Pulverized coal and stokers compete in the range from 35,000 to 150,000 lb per hr, with the number of pulverized coal installations increasing as the capacity increases. While there are a few installations of multiple-retort stokers for capacities above 150,000 lb of steam per hour and the traveling-grate type has been used for capacities as high as 275,000 lb, above this range pulverized coal, gas or oil are burned almost exclusively.

The amount of steam generated per foot of furnace width is lowest on small stokers and highest on the large pulverized-coal or oil-fired installations. To meet these varying conditions the boiler must be selected with the desired amount of heating surface, properly distributed, and with the proper drum sizes to provide the required steam space. Thus, it is apparent that capacity influences the type of fuel burning equipment and the latter, in turn, influences the selection of boiler.

Other Factors Affecting Boiler Design

Boiler design is further influenced by pressure, steam temperature and feedwater temperature. For relatively low steam temperatures with a bent-tube boiler, an intertube superheater can be used and the tube spacing and number of rows of tubes in the front bank arranged accordingly. For a higher degree of superheat, an interbank superheater located in front of or behind the first baffle of a bent-tube boiler would ordinarily be used. Above approximately 750 F the recommended location is interbank behind the first baffle. On the two-drum VU design the interbank arrangement is preferred for above about 100 deg of superheat.

In a similar manner, the sectional-header boiler design is influenced by steam temperature, the superheater being above the bank for small amounts of superheater and interdeck for higher superheat. The most desirable location of a superheater in the box-header type of boiler is above the bank, since the headers at the front and rear preclude the conventional interdeck arrangement. However, in a few cases cross-element type superheaters have been employed with such boilers, but the furnace width must be just right to give the desired element length and sufficient space must be available at the side of the unit to permit removal of the superheater elements.

While *per cent rating* has little meaning when applied to a modern steam generating unit, it does provide a means of comparing boiler surface in terms with which we are all familiar. A small unit, having sufficient heating surface to operate at 150 to 200 per cent rating, usually consists of boiler surface only, whereas larger steam generating units are generally made up of boiler, water walls, superheater, economizer and air heater.

The ideal combination of surfaces is that which will give the most economical unit; that is, the lowest initial cost to provide a justified efficiency and draft loss. If the feedwater temperature to the economizer is relatively low, it would be economical to design the unit to absorb more heat in the economizer than if the feedwater temperature were relatively high. In other words, the rating at which the boiler would operate with low feedwater temperature would be different for the same evaporation than were the unit designed for high feedwater temperature.

Up to approximately ten years ago, the conventional boilers in common use were the box-header, the sectional-header and the four-drum bent-tube types. The box-header type was employed for pressures up to 250 lb and for superheat below 150 deg. Sectional-header boilers were popular for large capacities and for lower pressures but were also extensively used for all sizes with pressures between 200 and 500 lb. Maximum steam temperatures

up to 750 F were obtained by the use of interdeck superheaters.

A smaller-percentage of units were of the four-drum bent-tube type, these usually being limited to around 400 lb pressure because of the limitations of riveting heavy plate and the presses then available for forming the drum plates. The relatively few installations for pressures above 500 lb employed forged drums. With the adoption of fusion-welded drums there has been a very large increase in the use of bent-tube designs, particularly of the three-drum type, for the entire range of capacities, pressures and steam temperatures, due to the improvements in manufacturing technique tending to decrease their cost. The three-drum bent-tube boiler, which has been used so extensively during the last few years particularly for high-capacity service, accomplishes everything that the four-drum type does, and possesses certain advantages over the latter. It has one less drum and is therefore less expensive; it is more compact and susceptible to a certain degree of standardization; it has provided adequate circulation; and has established proven performance. The two-drum, more or less standardized design, has proven capable of satisfactory operation for practically all pressure and temperature conditions met in the small and medium capacities.

Complete standardization of steam generating units, however, is not possible because of the varying conditions of pressure, superheat, capacities, fuel and space limitations.

A.S.M.E. Annual Meeting Program

The program for the Sixty-First Annual Meeting of the American Society of Mechanical Engineers, to be held in New York, December 2 to 6, has now been announced. Instead of having the sessions at the Engineering Societies Building as in former years, all sessions will this year be held at the Hotel Astor. The following excerpts from the program cover only papers on power or allied subjects.

MONDAY, December 2

8:00 p.m.

FUELS SESSION

Wood-Burning Space Heaters, by L. E. Seeley and F. W. Keator

The Significance of Coal-Ash Fusing Temperature in the Light of Recent Furnace Studies, by E. G. Bailey and F. G. Ely

MACHINE SHOP PRACTICE

Lubrication of General Electric Steam Turbines by C. Dantsizen

BOILER FEEDWATER STUDIES

Silica in High-Pressure Boiler Waters, by Harold Farmer

Silica Removal, by H. L. Tiger

Absorption Process for Removal of Soluble Silica from Water, by L. Drew Betz, Charles A. Noll and John J. Maguire

TUESDAY, December 3

9:30 a.m.

FUELS SESSION

Continuous Heat Balance Control of Boiler Room Operation, by B. S. Murphy

Flow Processes in Underfeed Stokers, by Martin A. Mayers

2:00 p.m.

DUST COLLECTION

Calculation of Cyclone Pressure Drop, by Franklin Miller and Marcel Lissman

Recent Developments of the Cyclonic-Spray Gas Scrubber, by Robert B. Kleinschmidt and A. W. Anthony, Jr.

POWER—FUELS

Steel Encased Settings for Modern Steam-Generating Units, by M. H. Kuhner

Some Particulars of Design and Operation of a Twin-Furnace Boiler, by John Blizard and A. C. Foster

WEDNESDAY, December 4

9:30 a.m.

POWER

A New Steam Engine and Boiler, by S. L. G. Knox and John I. Yellott

A Study of Circulation in High-Pressure Boilers and Water-Cooled Furnaces, by John Van Brunt

2:00 p.m.

LUBRICATION

Power Losses in High-Speed Journal Bearings, by F. C. Linn and D. E. Irons

Friction in Ball Bearings, by H. Styri

POWER—APPLIED MECHANICS

Solving Pipe Problems—A Mechanical Method for Cases Involving Temperature Expansion, by F. M. Hill

Condenser Tubes and Their Corrosion, by C. W. E. Clarke and A. E. White

Flow of Saturated Water Through Throttling Orifices, by Max W. Benjamin and John G. Miller

THURSDAY, December 5

9:30 a.m.

POWER—BOILER FEEDWATER

Problems of Boiler Feedwater Treatment at New High-Pressure Installation at Waterside Station, by Charles B. Arnold, Raymond T. Hanlon and Julius Mindheim

A New Degasifying Steam Condenser for Use in Conductivity Determinations, by F. G. Straub and Elwood E. Nelson

HEAT TRANSFER

The Radiation of Furnace Gases, by H. C. Hottel and R. B. Egbert

HYDRAULICS

Kaplan Turbine Installations of the Tennessee Valley Authority, by George R. Rich and J. F. Roberts

Turbine Discharge Metering at the Safe Harbor Hydroelectric Development, by J. M. Mousson

2:00 p.m.

HEAT TRANSFER

Remarks on the Analogy Between Heat Transfer and Momentum Transfer, by L. M. K. Boelter, R. C. Martinelli and Finn Jonassen

Vaporization Inside Horizontal Tubes, by W. H. McAdams, W. K. Woods and R. L. Bryan

HYDRAULICS

The Development of the Automatic Adjustable-Blade-Type Propeller Turbine, by R. V. Terry

Speed Regulation of Kaplan Turbines, by J. D. Scoville

EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

A High-Temperature Bolting Material, by A. W. Wheeler

An Investigation of the Effect of Grain Size and Structure on the Suitability of Carbon-Molybdenum Steel Pipe for High Temperature Steam Service, by A. E. White and Sabin Crocker

SYMPOSIUM ON POWER IN SHIPS

Marine Boilers: E. G. Bailey and L. M. Rakestraw

Marine Turbines: E. D. Dickinson and J. A. Davies

Marine Condensers: Paul Bancel and H. E. Carleton

The scheduled inspection trips include visits to the plant of the Yale & Towne Manufacturing Company at Stamford, Conn., the American Airlines shops at La Guardia Field, the East River-Midtown Tunnel, the Waterside Station of the Consolidated Edison Company, the New York factory of the American Can Company and the steamship *America*.

SOME EARLY BOILER DESIGNS

Excerpts from a compilation of the boiler designs offered principally between 1822 and 1873, many of which were built while others were merely patented. In these designs will be detected some of the basic features incorporated in modern design, indicating that the designers of that period were in advance of the facilities then available for putting their ideas into practice.

A MOST interesting treatise on boilers,[1] by N. P. Burgh, published in 1873, has just come to the attention of the EDITOR. Because of the many unique arrangements therein presented, it is believed that COMBUSTION readers will find a description of some of these designs of particular interest in revealing the ingenuity and thinking of engineers of those days.

The author covers the period from 1663 to 1873 during which more than three thousand boiler designs were offered for patent protection and many were built. Of these, the author selected and described 748, only a few of which are here reproduced because of space limitations.

Passing over such early boilers as those of Savery (1698), Newcomen (1710), Smeaton (1769), Watt (1788–1800) and Evans (1804), descriptions of which are to be found in many textbooks, it is noted that there was very little activity from 1800 to 1822, but the period from 1822 to 1873 was most prolific in the number and variety of designs offered.

Vertical Boilers

In 1822 Clark brought out what the author believed to be the first water-tube boiler design. As shown in Fig. 1 this was composed of a series of 1-in. curved copper tubes surrounding the combustion chamber and attached top and bottom by means of ferrules to cast-iron plates forming headers. Bolts and flanges were employed to hold the components together and the tubes were curved to compensate for expansion.

Two years later Moore, an Englishman, designed the vertical water-tube boiler shown in Fig. 2, which consisted of three horizontal ring pipes connected by vertical and angular water tubes. The bottom and intermediate rings, as well as the tubes up to this level, contained water and the upper portion of the tubes and the top ring contained steam.

What appears as a forerunner of the mechanical stoker is seen in Fig. 3 which represents the Holmes annular-flue boiler with a revolving grate developed in 1836. The fuel was fed from the hopper by a toothed roller actuated by a worm on the upper end of the vertical shaft which, in turn, was driven by a horizontal shaft that also caused the grate to revolve.

From 1836 to 1851 little was done to improve the vertical boiler but in 1852 Craddock brought out a design which had outside return flues. The top and bottom chambers were of wrought iron and to these the tubes were attached by ferrules. Plugs were inserted in the plate opposite each tube to permit tube removal.

Passing to 1853 Cowper designed the boiler shown in Fig. 4, the shell of which was formed by flat cells or water spaces which were connected and stayed. These cells were tapered, being narrower at the bottom than at the top and each connected by one pipe to the steam chamber and by another to the water chamber. In an effort to prevent deposits in the cells, each was provided with a second set of pipes communicating with the water chamber over the main flue to promote circulation. That is, the water in the chamber being less exposed to heat than that in the cells, there was less ebullition and the sediment was expected to settle to the bottom of the chamber where it could be blown off.

Another unusual design was patented by Ferinhough in 1856. This as shown in Fig. 5 is of the vertical water-leg type with internal steam chests.

From 1855 to 1859 Chaplin brought out a number of designs of vertical fire-tube boilers in which the tubes were made conical for half their length and parallel for the other half. One of these designs employing curved contracted tubes is shown in Fig. 6. In some of his designs the tubes were contracted in their upper portion, presumably to compensate for the reduced volume as the gases cooled, but just why he should have reversed this arrangement in the design shown is not apparent.

Although the coil boiler was introduced by Bellford in 1853, Matheson in 1861 presented a design shown in Fig. 7, fitted with horizontal water coils and an overhead water and steam chamber, as well as a bottom header. The water reservoir at the top having been supplied by the feed to the proper level, the water passed through the blowoff pipe, or external downcomer, to the bottom reservoir, thence filled the coils. As steam was generated in the coils it passed out through the vertical pipes whose ends extended above the water level, under a deflector or water "priming cap" and was taken off from the steam space; thus a positive circulation was claimed.

Williamson in 1861 was responsible for a water-tube boiler (Fig. 8) in which concentric tubes were employed, the water passing through the outer tubes and the steam through the inner tubes. It would appear also from the plan view that he employed the equivalent of water walls surrounding the furnace. He also invented an A-type of boiler as shown in Fig. 9 which was fitted with twin grates.

The vertical cylindrical design patented by Messenger in 1869 (Fig. 10) employed large water tubes in the firebox and a spiral coil in the flue through which the feed-

[1] "Boilers, Practically Considered", by N. P. Burgh, published by E. & F. N. Spon, London and New York, 1873.

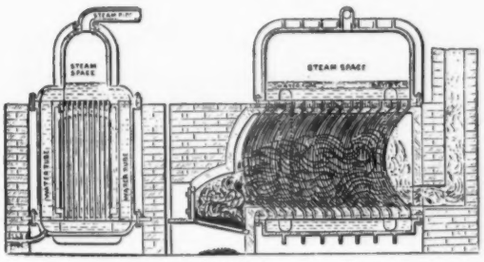


FIG.1

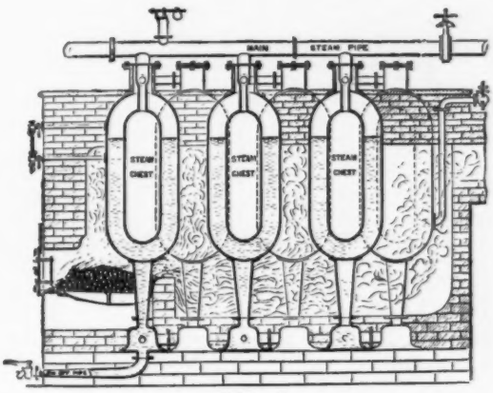


FIG.5

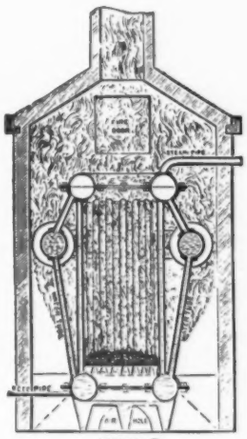


FIG.2

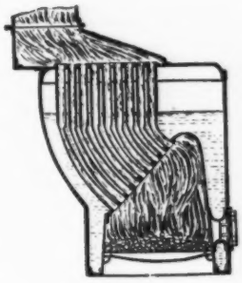
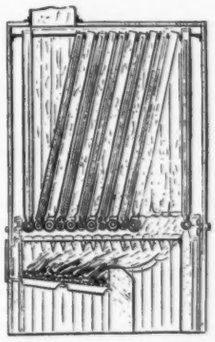


FIG.6



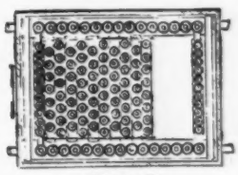


FIG 8

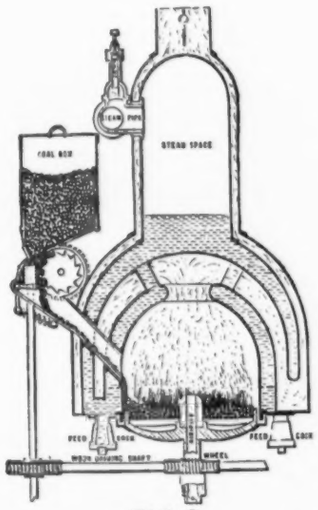
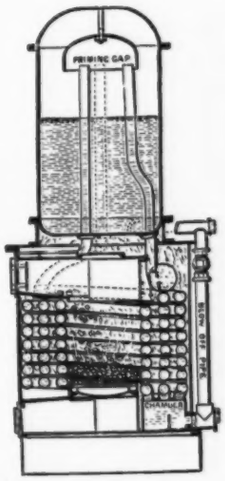


FIG.3



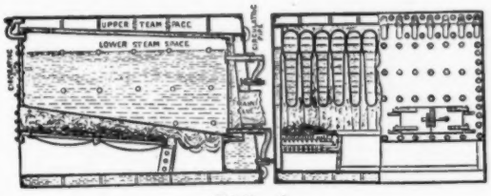


FIG.4

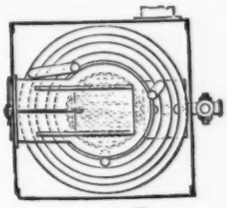


FIG.7

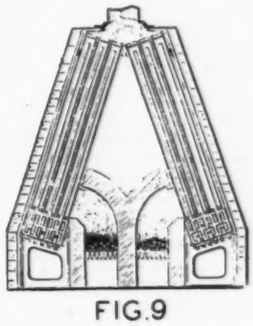


FIG.9

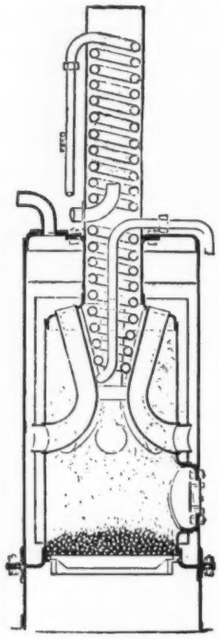


FIG. 10

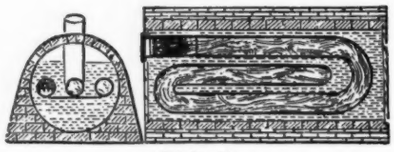


FIG. 11

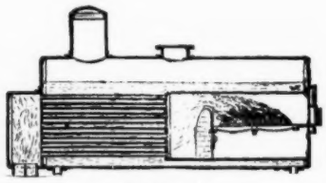


FIG. 12

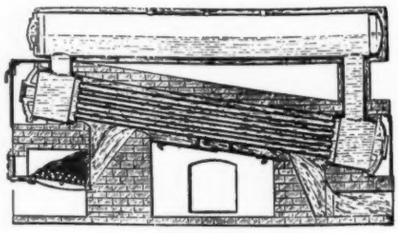


FIG. 13

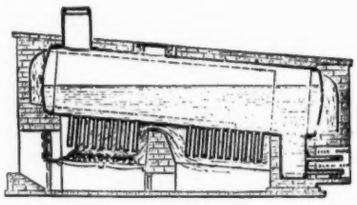


FIG. 14

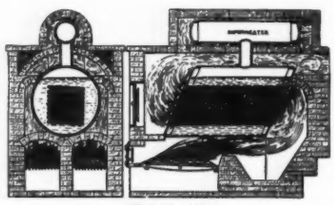


FIG. 15

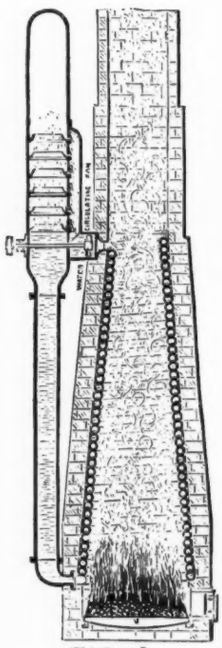


FIG. 16

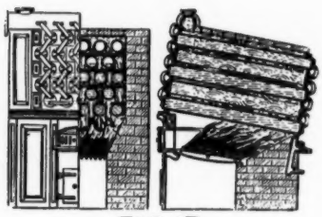


FIG. 17

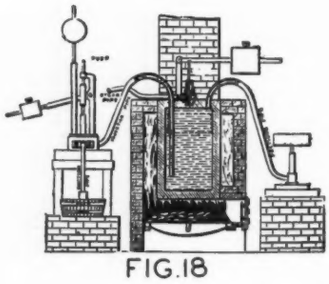


FIG. 18

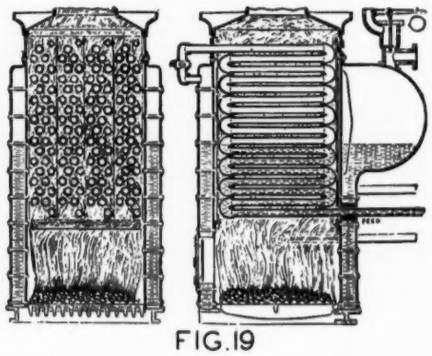


FIG. 19

water was introduced. This involved the principle of an economizer.

Horizontal Boilers

As for horizontal boilers, that developed by Brindley and installed at Cornwall in 1800 is said to be the first of the fire-tube type. The 20-in. tube (see Fig. 11) which traversed the furnace three times was made of copper and the shell of the boiler was of granite. A similar boiler was shortly thereafter constructed by Watt in which the containing shell was of wood.

An approach to some more recent designs is to be found in the Schofield horizontal cylindrical boiler of 1852 as shown in Fig. 12.

Similarly, a low-set horizontal water-tube boiler with a longitudinal drum and water chambers at each end of the tube bank was brought out by Inglis in 1863 as shown in Fig. 13.

The Fields' horizontal cylindrical boiler with water tubes projecting from the underside of the shell into the furnace, as shown in Fig. 14, was designed in 1866. There was also a water leg with blowoff connection at the rear of the drums.

Holt in 1867 came forward with a design of return-tubular boiler in 1867 (Fig. 15) which was provided with a dry drum swept by part of the gases, which he designated as a superheater. The ends of the tubes were flared but this tended to weaken the tube sheets.

A design employing the principle of assisted circulation was brought out by Elder in 1862 as shown in Fig. 16. This consisted of a spiral coil set in a vertical position in the brickwork, both ends being connected to the water column at the left. The upper branch contained a screw propeller to produce downward circulation of water through the coil. Above the water column was the steam chamber fitted with drying rings.

A forerunner of the sectional header boiler is to be found in the Ashbury boiler of 1669, shown in Fig. 17. This consisted of inclined water tubes connected at each end through flanges by pipes and equipped with a small cross steam drum. The same inventor also brought out, about the same time, a design in which the inclined water tubes, in pairs, entered flat water boxes front and rear, the upper ends of which connected with steam drum. This, in a sense, was a prelude to the box-header type.

Injection Boilers

Going back some forty to fifty years previous to this period there was an era in which a number of so-called injection boilers were proposed. These usually contained a minimum amount of water and the steam required by the engine at each stroke was provided by the hot water flashing into steam, the water being injected into the boiler as required.

The first injection boiler appears to have been invented by Jacob Perkins, an American, and a proponent of high pressure, who introduced the design in England in 1822. This is represented by Fig. 18. The boiler had a copper cylinder with walls three inches thick and completely filled with hot water at a pressure of 7500 lb per sq in. As more water was forced in by the feed pump a like amount was displaced and flashed into steam as it entered the engine cylinder. This cycle was repeated at each engine stroke. Perkins also brought out in 1855 a horizontal continuous water-tube design employing the injection principle.

Reference will be made to one other injection boiler which was proposed by Benson in 1858. This individual is not to be confused with Mark Benson who brought out the present-day Benson boiler some fifteen or twenty years ago. The early Benson boiler, Fig. 19, was composed of inner and outer shells, the space between them serving as water and steam space, while the central portion was occupied by continuous coils through which water was forced by a pump. The upper end of the coil communicated with the space between the inner and outer shells.

As an illustration of the ingenuity of this period mention may be made of an American, named Scott, who invented and introduced, about 1858, a revolving-tube boiler of the injection type, thus anticipating the introduction of such a type in Europe some sixty years later. The Scott arrangement consisted of a horizontal coil in the form of a helix, suspended in the furnace, and caused to rotate by being attached to a gear at one end. Water was introduced through a stuffing box at the front end of the coil and steam was taken off through a stuffing box at the rear. The water was injected as required to supply the amount of steam taken by each stroke of the engine, and the coil rotated at the rate of one revolution per minute.

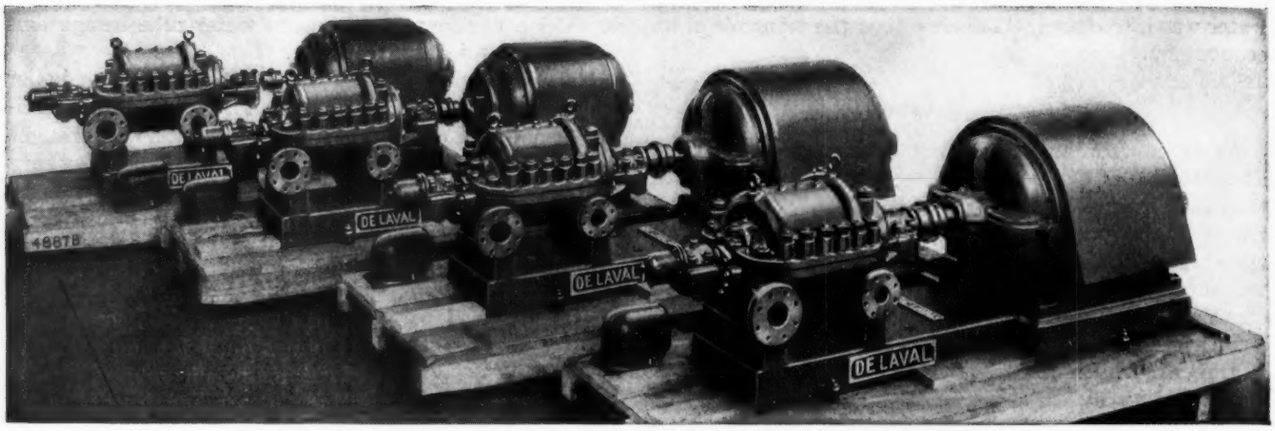
The author illustrates twenty-eight different designs of injection boilers offered between 1822 and 1853, some for pressures greatly in excess of those attempted even today. Many of these inventors were far in advance of the ability of metallurgical developments to carry out their ideas. Also, while exact information on the properties of steam and data on combustion and heat transfer were then too meager to warrant rationalized design as we know it today, these pioneers nevertheless exhibited considerable ingenuity and proposed certain basic ideas that have since been put into effect.

Industrial Power Survey

The Federal Power Commission is now engaged in making an industrial power survey for the purpose of determining whether there is ample power available in certain areas and in plants that are making munitions or are likely to receive Government orders, and to anticipate well in advance any power shortages that are likely to occur.

Approximately twenty-five thousand industrial establishments are being asked to fill out questionnaires giving data as to the source of power supply if purchased, or installed capacity if generated; also, the energy purchased or generated in 1939, that anticipated for 1940 and 1941, and the proportion of this used in filling Government contracts.

This information will supplement the survey already made of utility systems, as a result of which complete monthly reports are now being made to the Commission. The combined data, when coordinated, will permit plans being made in time to assure adequate power and will also serve to forecast load growth.



Four motor driven boiler feeders; 300 g.p.m. each of 212° F. water against 750 psi. at 2900 r.p.m.

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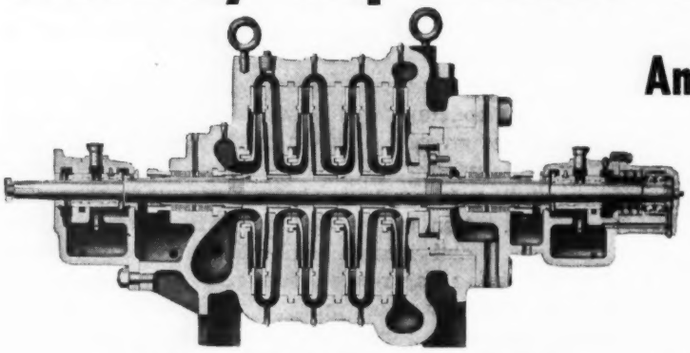
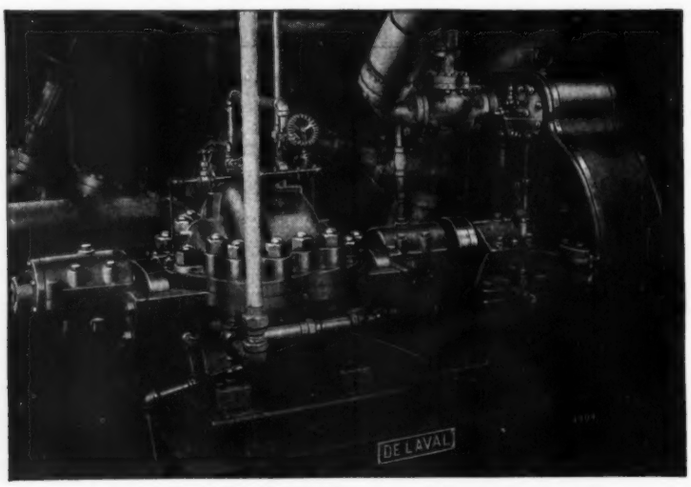


Diffusion type multistage pump with sleeve bearings.



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Removal of SILICA

With industrial plant boilers employing a high percentage of makeup and steam pressures of 400 lb and over, removal of silica often presents a problem, especially if the silica occurs in a soluble form. The authors discuss the several methods of removal, particularly by adsorption, with magnesium as a reducing agent.

FROM INDUSTRIAL BOILER-WATER SUPPLIES

By **S. E. TRAY*** and **T. L. PANKEY†**

CURRENT interest in methods of removing silica from water used for boiler feed is not only a tribute to the advancement of the science of water treating, but is indicative of the important rôle which research plays in the development of steam and power generation. Only a few years ago sodium silicate in various forms was in common use in boiler compounds, designed to prevent scale and corrosion. As operating pressures and temperatures increased, coincident with the development of the modern, high-pressure steam generator, it became apparent that silica scale was one of the major problems to be overcome. In central stations, however, operating with low percentages of makeup supplied from evaporators, silica did not present too great a problem even at high operating pressures. It was only with the adoption of high pressures above 400 lb by industrial plants requiring large percentages of makeup water, that the problem of silica removal began to receive serious consideration.

Occurrence of Silica

The necessity for silica removal is readily apparent when the widespread occurrence of the element in all natural waters is considered as well as the effect of silica deposits in both boilers and turbines. It is one of the most abundant compounds found in nature, occurring in rock formations, sand and gravel and is readily dissolved by water flowing through these formations. The silica content of natural waters varies in different localities but is generally higher in softer waters. Thus the Pacific Northwest and the Gulf Coast area have relatively soft waters with a high silica content, while some of the hard waters in the Middle West contain very little.

Silica may be present in water as soluble silica in solution, or as colloidal, suspended silica. Often it is found in both forms simultaneously. The suspended silica is easily removed by coagulation and filtration or settling. It is the soluble silica, on the other hand, that is most difficult to remove and it is this soluble form that is most objectionable in boiler feedwater. Silicates are not simple compounds, such as the sulphates and phosphates, but may exist in combination with numerous other constituents. Usually silica deposits in boilers are very thin, but, because of their density, have the lowest heat transfer rates of any type of scale. Such deposits on turbine blades are generally insoluble and cannot be washed off, but require elaborate chemical and mechanical cleaning.

Adsorption Process

The usual methods of external softening have practically no effect on reducing soluble silica. Instances have been reported of the reduction in silica by ordinary hot lime-soda softening, but Schwartz (1) pointed out in his comprehensive treatise on silica, "Such reduction is incidental and accidental" and cannot be relied upon as an effective means of silica removal. Such instances are probably due to the natural magnesium content of the raw water.

Early investigators in the field noted that the silicates were too soluble to permit removal by the usual precipitation methods used in ordinary softening. Hence, the numerous methods which have been suggested for the removal of silica all depend on its adsorption by some chemical introduced into the water. The adsorption process has long been the basis of the dye industry and has found wide application in other fields as well. In water purification, the removal of color and odor by activated carbon is a familiar adsorption phenomenon.

Theory of Adsorption

Adsorption may be differentiated from precipitation by the fact that in an adsorption process no definite compound can be identified and that the quantities of adsorbent and material adsorbed are not in constant molar ratio. Adsorption is more a physical process by which ions in solution are concentrated at the surface of colloidal particles of opposite charge and thus removed from solution.

It is known, for instance, that magnesium hydroxide in a colloidal condition will selectively adsorb silica on the surface of the insoluble hydroxide. The rate of adsorption varies with the quantity of magnesia used, the initial concentration of silica in the water, the temperature, and most critically with the selective character and colloidal condition of the magnesia. Freundlich has found that most adsorption results yield parabolic curves when plotted, and can therefore be most conveniently handled by using logarithmic coordinates which

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† Research Engineer, Water Treating Division, Allis-Chalmers Manufacturing Co.

convert the parabolic linear curves to straight lines. If the values of a particular process lie on a straight line Freundlich isotherm, the process may reasonably be supposed to be a true adsorption process. The colloidal condition and selective adsorption value of the magnesia depend upon the hydration characteristics of the magnesia. This is in accordance with the theory of Von Weiman, which states that the rate of particle growth of the material, as well as the initial particle size, is determined to a considerable extent by the conditions of

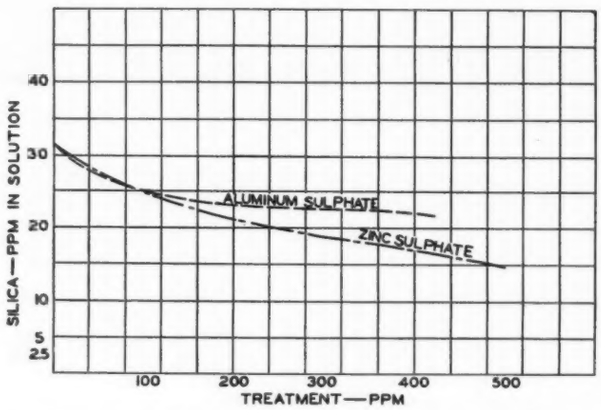

Fig. 1—Effect of aluminum sulphate and zinc sulphate on silical removal

initial precipitation. From this point of view, it is easily understood why all forms of magnesia are not suitable for silica removal.

Previous Methods of Silica Removal

Among the earlier methods suggested for the removal of silica were the use of magnesium salts and the soluble sulphates of zinc, iron and aluminum. These have been used in the cold as well as in the hot, but the most effective results in most cases were obtained at higher temperatures near the boiling point. The costs involved in some of these suggested methods have precluded their general use. Moreover, the residual silica remaining after treatment has not been sufficiently low to justify the increased cost of operation. Fig. 1 shows the results obtained in an actual plant with both aluminum and zinc sulphate. The very high dosages required for only partial removal of the silica indicate the limitations of these methods.

In 1938 Schwartz (1) reported the results of an investigation involving a great number of different chemicals for removing silica from Mississippi River water. Of all the materials tested, best results were obtained with ferric sulphate in the cold, and they appeared of sufficient interest to warrant the adoption of this method in a large utility plant furnishing both steam and power to industrials. Subsequently this treatment was installed in several other plants where the removal of silica appeared to be essential. All of the sulphates have the disadvantage that the sulphate ions remain in the water to increase the total solids. In the case of iron salts additional equipment is also required in many cases.

The effect of magnesium on reducing silica was noted by Christman, Holmes and Thompson (2) in 1931. Straub (3) in 1936 studied the effect of large excesses of magnesium oxide and magnesium carbonate in synthetic boiler waters and found a large reduction in silica with their use. Geisler (4) in 1937 described the use of powdered magnesium oxide in a hot-process softener to reduce the silica as low as one part per million. That these methods of silica reduction were not adopted before on a wider scale has been due to the lack of a cheap and effective form of magnesium, as well as a definite procedure for handling the material in plant operation.

Effect of Different Forms of Magnesium

The natural magnesium content of certain raw water supplies is of some benefit in reducing the soluble silica. Generally speaking, however, there is not sufficient magnesium present to effect complete reduction in silica. Such ionic magnesium may be supplemented by magnesium added externally, and complete reduction obtained. At one plant silica was reduced from 22 ppm to 15 ppm by the magnesium in the water; at another silica was reduced from 23 ppm to 9 ppm in the same manner. Where silica is a problem such a reduction is not sufficient. A survey of the operation of over fifty softeners in various parts of the country shows that reduction of silica by the magnesium present in the waters occurs with widely varying efficiency and is sel-

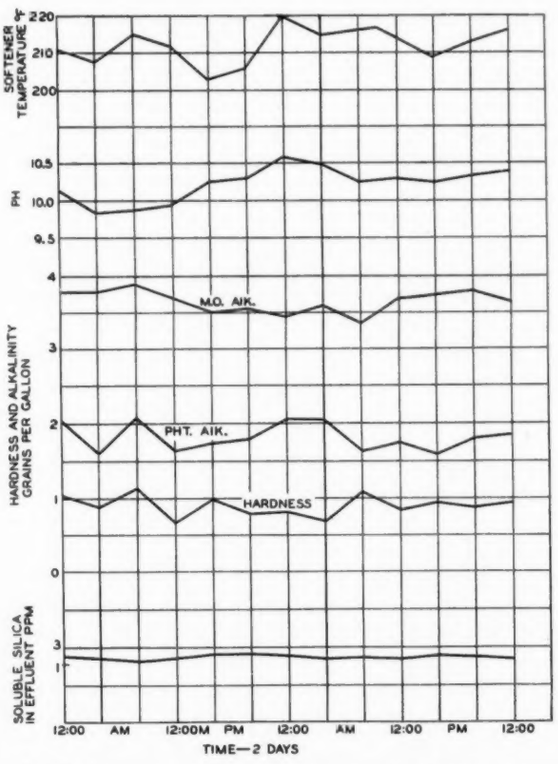

Fig. 2—Hot-process softener operation for silica removal

dom great enough to be of substantial value. This is particularly true of the extremely soft waters containing 25 to 60 ppm silica which are commonly found in the South.

Several forms of magnesium are now available including a special activated lime containing magnesium, which combines the effective adsorptive properties of magnesium with the softening properties of calcium. In

this connection it is interesting to note that all forms of magnesium are not suitable for silica removal. Behrman and Gustafson (5) have reported on a series of tests with dolomitic lime from various sources, none of which were effective in reducing silica. Geisler (4), in his tests with magnesium oxide, noted that the density of the material was very important. He also reported that magnesium oxide from various sources gave widely different results. Betz, Noll and Maguire (6) have studied the effect of various forms of magnesium on silica reduction and, on the basis of laboratory results, have reached substantially the same conclusions. The results reported herein were all obtained with activated lime containing magnesium.

Silica Removal in Hot-Process Softeners

While silica removal with magnesium can be obtained in the cold as well as in the hot, the hot-process softener is widely used for external softening of boiler feedwater. Thus it was felt that if silica removal could be accomplished along with softening in this type of equipment, it would be a distinct advantage to plants already operating these softeners. Early in the research it was realized that any material used for silica removal must be easily controlled and stable in effect throughout the usual ranges of softener operation. Data secured from actual plant performance show that these characteristics have been readily obtained. In Fig. 2 plant data on a typical hot-process installation have been plotted. During this run, hardness, alkalinities, pH values and temperature varied over a wide range, while the silica content of the effluent remained stable within a range of one part per million.

The importance of this feature of operation cannot be over-emphasized in industrial water treatment. Operating costs do not permit employing trained chemists at all hours of the day; the operation must be stable within broad limits which can be maintained without major adjustment by an average operator. During the first ten days of operation at the plant from which the data in Fig. 2 were taken, six different operators were in charge of the water-softening plant. Nevertheless, silica removal was steadily maintained. Silica removal can be evaluated only on the basis of continuous averages. Momentary reductions in silica to less than one part per million are of no value to the system if the average is 5 ppm.

In hot-process treatment, activated lime containing magnesium and soda ash are introduced into the softener and operation is carried on in the same manner as with normal softening. The conditions for uniformity are controlled to insure maximum silica removal within the usual one-hour retention period. Fig. 3 shows the rate of removal of silica from a water having an initial concentration of 26.4 ppm of silica. In this case the soluble silica was reduced to 1.2 ppm in one hour.

The sedimentation tank in a hot-process softening system serves not only as a chemical reaction tank, but also as a means of separating the precipitated sludge from the treated water. The volume of sludge is greater when using magnesium, but the magnesium creates a heavy, voluminous floc which collects a large part of the fine suspended material and carries it to the bottom of the tank. Since coagulation in the sedimentation tank is improved, no additional coagulant is required and a lighter load is imposed upon the filters. A small amount of sludge from the sedimentation tank is always carried out to the filters and deposited in a uniform bed. In fact, no washed filter is fully effective until a proper sludge bed has been formed. The magnesium floc forms a sludge bed that is much more efficient than that produced by the usual carbonate sludge, without increasing the loss in head through the filters.

Silica Removal in the Cold

The removal of silica with magnesium in the cold is less effective than in the hot. In comparison with other chemicals, however, magnesium has far greater adsorption properties providing proper contact of the water with the precipitated sludge can be obtained. A relative measure of the efficiencies of various chemicals suggested

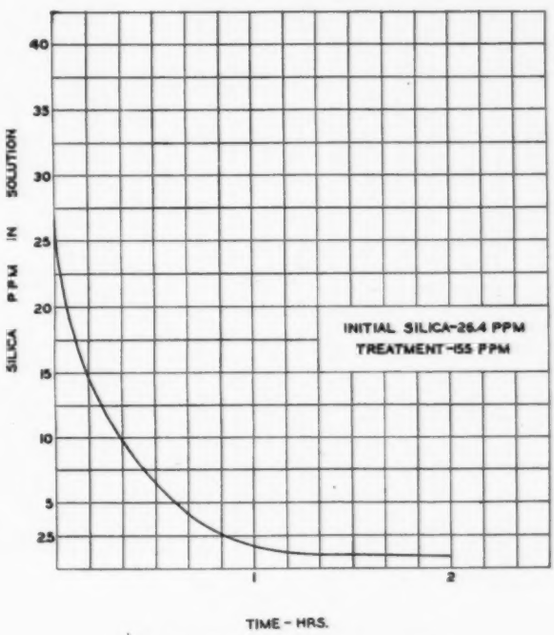

Fig. 3—Rate of silica removal

for silica removal can be obtained by plotting their Freundlich isotherm lines. This is the relation on a logarithmic scale between the amount of silica adsorbed per part of reagent used and the residual silica after treatment. Fig. 4 shows this relationship for various chemicals on the same water.

The removal of silica in the cold requires more intimate sludge contact with the water if results are to be obtained comparable with treatment in the hot. The time element is also an important factor since commercial installations are usually restricted in size to provide for a relatively short retention period. It is very fortunate that the development of equipment designed for accelerated softening and clarification in the cold has been contemporary with the progress in silica removal. By providing for this intimate sludge contact, these accelerated softeners, in effect, reduce the time required for adsorption and provide the proper conditions for the removal of silica in the cold. The ordinary cold process softener using a batch treatment can also be employed for removing silica. However, the time required for agitation and settling is somewhat longer than for ordinary softening.

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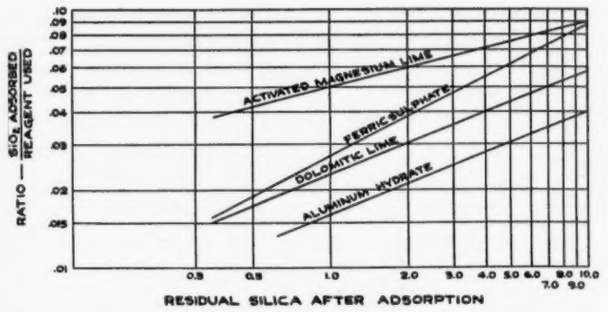

Fig. 4—Efficiency of various chemicals for silica removal in the cold

A number of installations have been made in which preliminary softening and silica removal are followed by zeolite treatment or external phosphate softening to further condition the water for boiler-feed purposes. Under these conditions, it is absolutely essential that the treatment for silica removal shall not increase the total solids after treatment. In a large measure this would defeat the purpose of complete external treatment which is designed to reduce the total solids as well as the hardness in boiler-water makeup. The concentrations which can be carried in high-pressure, high-makeup boilers are usually limited by load conditions and boiler design, and should not be further limited by water available.

Treating Costs

No discussion of silica removal would be complete without reference to capital investment and operating costs. Too often in the past, methods of silica removal have been proposed which involved elaborate equipment and cost of treatment far beyond that which could be economically justified. Operating costs ranging from 3 to 5 cents per thousand gallons for silica removal alone, exclusive of softening, have been proposed in many instances. Obviously, except in unusual cases, this cost is excessive, and as a consequence many plants are operating with a silica problem rather than increasing their water-treating costs. From a survey of a number of representative installations now operating it is apparent that the average cost of silica removal will range from 0.9 to 1.2 cents per thousand gallons, exclusive of softening. Likewise, where external lime-soda softeners of any type are available, no capital investment for new equipment is required.

In the removal of silica, as in other water purification methods, the chemical characteristics of the raw water supply govern the requirements for treatment. The adsorption of silica requires the conversion of magnesium to the hydroxide. The effectiveness of magnesium in removing silica depends upon the condition of the hydroxide in contact with silica in solution. The development of these principles together with establishing a definite control procedure in the plant has given to the power industry a definite means of combating silica.

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Modernizing Settings of Traveling Grate Stokers

By lengthening the stoker, increasing the setting height and replacing the front arch with a long rear arch, it is possible to adapt old traveling grate stoker installations to burn buckwheat No. 4 or reclaimed river coal with good efficiency and large savings in fuel cost. Many such installations have been so revamped and the savings have paid for the changes in two to three years.

By O. J. MACAN

Combustion Engineering Company, Inc.

DURING the last decade, furnace designs for traveling grate stokers have undergone radical changes. Originally such furnaces had long front arches only and the highest windbox pressure was carried in the front air compartment of the stoker when burning anthracite. With this design of furnace the gases traveled to the rear and at high rates of burning considerable of the fines were blown to the rear of the stoker and carried into the ashpit. This materially increased the carbon loss in the ash.

Such a design of furnace also permitted the infiltration of air at the rear of the stoker, the air finding its way in through ashpit doors, through the ash-hopper gates, or underneath the stoker, and eventually passing up the

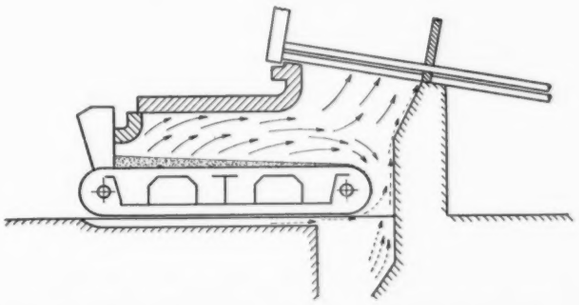

Fig. 1—Early installation of traveling grate stoker with long front arch under a low-set straight-tube boiler

front of the bridgewall and into the tube bank. The result was that very little of this air mixed to any considerable extent with the combustion gases.

At the time these front-arch settings were installed No. 3 buckwheat, or barley, was the commonly used fuel for traveling grate stokers of the bar and key type and maximum combustion rates of 35 to 38 lb of coal per square foot of grate surface per hour were the usual basis of figuring stoker sizes. The sketch, Fig. 1, represents such a furnace and stoker under a low-set straight-tube boiler.

On the more recent installations of traveling grate stokers for burning anthracite the arches have been completely changed. The long front arch has been replaced by a short front ignition arch and a long low practically flat rear arch is installed over about two-thirds of the stoker. With this arrangement the highest windbox air pressures are carried well toward the rear of the stoker under the rear arch and the combustion gases travel forward over the fuel bed. Much of the fines blown off the fuel bed are consequently deposited at the front of the stoker and are ignited, and most of the remaining

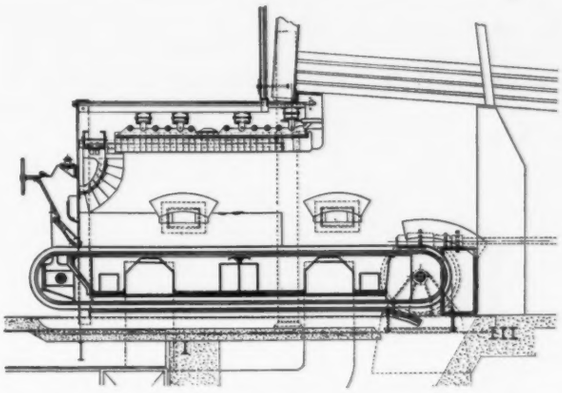

Fig. 2—Early Coxe traveling grate stoker with long front arch for burning No. 3 buckwheat

fines are carried in the whirling gas stream and burned in suspension.

The stoker is practically sealed off at the rear, which means that any infiltration of air at the rear end of the stoker must find its way along underneath the arch and thus tends to keep the latter cool. The air is finally caught in the high-pressure gas zone and mixes with the rich gases passing off the fuel bed at the front of the stoker.

In designing these more recent settings thought was given to the burning of the cheaper and smaller grades of anthracite such as No. 4 buckwheat and reclaimed river coal which could not be burned at high combustion rates with the older settings without excessive carryover of fines, as well as reduced capacities and much lower efficiencies. The stoker sizes were therefore increased so as to bring the combustion rates down to 26 or 28 lb per sq ft of grate surface per hour. This permitted comparable evaporative capacities, even with the poorer grades of fuel and further savings because of its lower price.

It is possible to lengthen most of the old traveling

grate stokers and rebuild the furnaces along modern lines. This has been done in many cases. Fig. 2 represents an early Coxe traveling grate stoker under a straight-tube boiler, with low setting and long front arch, originally designed for burning No. 3 buckwheat. This was recently lengthened, the boiler raised 6 ft, and the furnace provided with a long rear arch and short front ignition arch as illustrated in Fig. 3. With this setting No. 4 buckwheat or river coal is burned very successfully with good efficiency. In many cases, however, it is not necessary to raise the boiler.

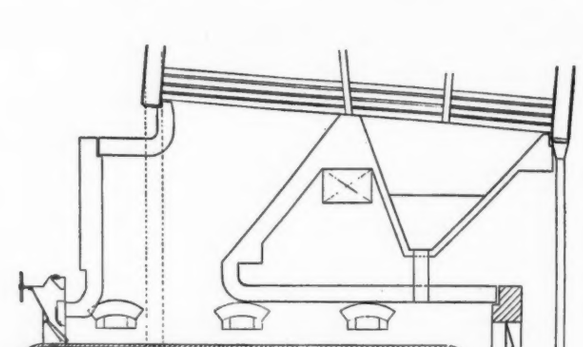

Fig. 3—Installation shown in Fig. 2 after lengthening stoker, raising setting and replacing front arch with long rear arch for burning No. 4 buckwheat

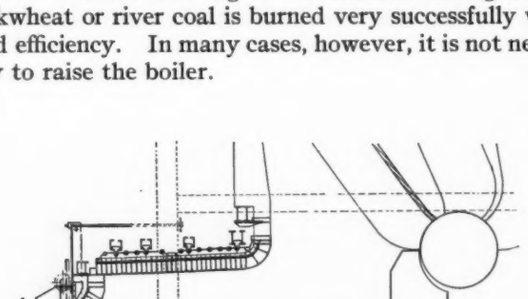

Fig. 4—Traveling grate stoker with front arch under bent-tube boiler, designed some years ago for burning No. 3 buckwheat

Fig. 5—Installation shown in Fig. 4 after revamping setting, lengthening stoker, applying long rear arch and changing baffling; No. 4 buckwheat or river coal burned successfully

Another early installation of a Coxe traveling grate stoker, under a bent-tube boiler with longitudinal baffles and a long front-arch furnace designed for burning No. 3 buckwheat, is shown in Fig. 4.

This stoker was lengthened, the boiler baffling changed and the front arch replaced by a long rear arch extending well under the bottom drum, as in Fig. 5. With this changed setting No. 4 buckwheat or river coal are burned satisfactorily with marked savings in fuel cost.

Comparative Results, Before and After Modernizing Stoker and Setting

The following tabulation gives the approximate results with a typical old design of stoker and front-arch setting, burning No. 3 buckwheat, compared with the same stoker and furnace after being modernized to burn No. 4 buckwheat. These figures will vary slightly with setting heights, size of stoker and the furnace arrangement.

Early installation of traveling grate stoker with old style front arch setting:

Stoker, 146 sq ft
Boiler, 600 hp
Rating, 200 per cent
Fuel, No. 3 buckwheat
Evaporation, 7.7 lb per lb of fuel
Efficiency, 65 per cent
Btu per lb, 11,500
Fuel price, $3.30 per ton

Example:

$$\frac{600 \times 2 \times 34.5 \times 970}{11{,}500 \times 0.65} = 5400 \text{ lb of coal per hr (approx.)}$$

This corresponds to a combustion rate of 37 lb of coal per square foot of grate surface per hour.

$5400 \times 7.7 = 41{,}580$ lb of steam per hr
$= 41.58$ thousand lb per hr
$5400 \div 2000 = 2.7$ tons per hr
$2.7 \times \$3.30 = \$8.91$ fuel cost per hr (No. 3 buckwheat)

$$\frac{\$8.91}{41.58} = 21.4 \text{ cents per 1000 lb of steam}$$

Same stoker lengthened 4 ft 8 in. and setting modernized:

Stoker, 195 sq ft
Boiler, 600 hp
Rating, 200 per cent
Fuel, No. 4 buckwheat
Evaporation, 8.16 lb per lb of fuel
Efficiency, 72 per cent
Btu per lb, 11,000
Fuel price, $2.40 per ton

Example:

$$\frac{600 \times 2 \times 34.5 \times 970}{11{,}000 \times 0.72} = 5100 \text{ lb of coal per hr (approx.)}$$

This corresponds to a combustion rate of 26 lb of coal per square foot of grate surface per hour.

$5100 \times 8.16 = 41{,}616$ lb of steam per hr
$= 41.6$ thousand lb per hr
$5100 \div 2000 = 2.55$ tons per hr

$2.55 \times 2.40 = \$6.12$ fuel cost per hr (No. 4 buckwheat)

$$\frac{\$6.12}{41.6} = 14.7 \text{ cents per 1000 lb of steam}$$

Summary:

$0.214 per 1000 lb of steam (old setting)
$0.147 per 1000 lb of steam (rebuilt setting)

$0.067 saving per 1000 lb of steam

With approximately 42,000 lb of steam per hour, an 8-hr day would involve 336,000 lb of steam or with 300 working days for the year, this would mean 100,800,000 lb per yr.

$100{,}800 \times 0.067 = \$6753$ yearly saving in the fuel cost

Yearly savings approximating the above figures means a return on the money expended for the modernization of $33\frac{1}{3}$ to 50 per cent. In other words, a rebuilt stoker and furnace would return the cost of the installation in two to three years. At the present time when many industrial plants are running two shifts the return on the investment would be doubled and the installation pay for itself in half the above time. Similarly, with a 24-hr. load the return would be trebled and the time reduced proportionately.

Where a plant has further need for increased capacity this can often be accomplished with the rebuilt stoker installation providing the boiler is satisfactory for the higher ratings.

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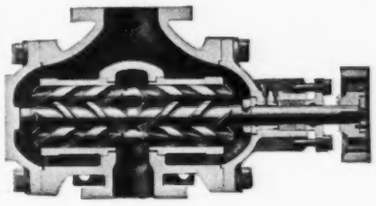

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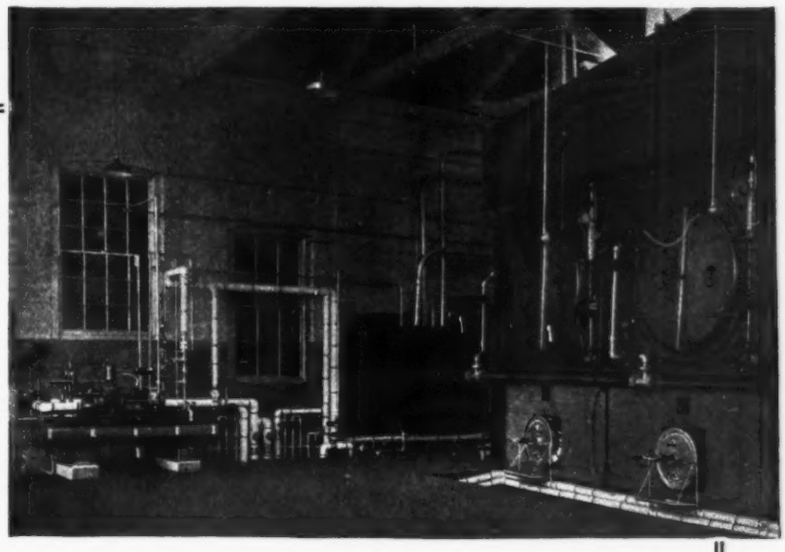

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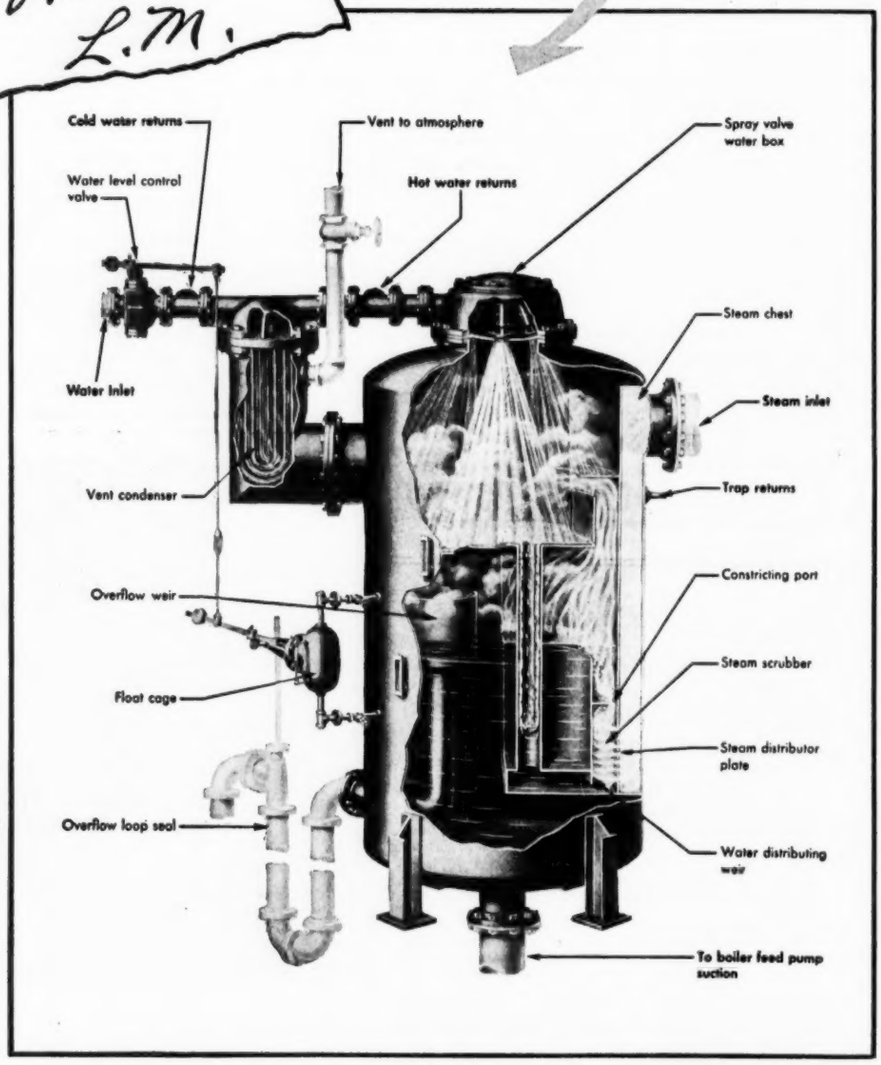

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FUEL OIL BURNING

By ZUCE KOGAN

Consulting Engineer, Chicago

After reviewing briefly the major concepts on which the widely accepted theory of fuel oil burning is based, the author offers a new approach to the problem which differs from the traditional concepts. He shows how modern practice tends to support this theory.

THE traditional concept concerning the burning of fuel oil was based on two major premises, namely:

1. That each oil globule leaving the burner has what can be described as a liquid heart, or core, and that this can only be completely consumed as the oil globule meets the air and has its outer surface burned off in the process of flowing toward the outlet of the furnace.

2. That the heat within the furnace and the heat radiated by refractory walls serve to ignite the fuel on the outside surface of the globule and in this way help to keep the globule burning during its passage through the furnace.

Over a period of time these two premises came to be accepted unquestioningly and out of them grew several conclusions which not only had their effect on methods of oil burning but also exerted a noticeable influence on furnace construction. These conclusions were:

1. That considerable time is necessary for the oil globule to burn itself out on the outside surface until the last particle of fuel inside the core is consumed.

2. That the length of path in the furnace had to be ample, in order to permit the globule to burn through to its liquid core before meeting the relatively cold heating surface at the end of its path.

3. That refractory all along the path of travel was necessary in order to prevent the globule from cooling below the ignition temperature at any point, otherwise ignition would not be maintained.

These concepts developed in a period when little progress was being made in the field of fuel burning. Their acceptance, however, has been so widespread that many engineers still hold to the dependency on time for contact between the oil and air particles, long flame travel, and abundance of refractory as the means of insuring complete combustion.

As changing conditions dictated the need for boilers and furnaces of different design, however, it began to be apparent to some that factors other than those referred to could be brought into play and that these other factors would reduce the dependence on contact time, flame path travel and on refractory. Thus, even though to the author's knowledge, no articulated disavowal of the traditional approach to the burning of fuel oil appears in literature on the subject, the current trend in practice is toward reduced dependence on these three factors.

To illustrate this lag between theory and practice and to show that the trend today is toward shorter furnaces with shorter flame travel, attention might be called to the so-called "package type boiler" in the domestic field, the furnace of which in plan approximates a square. In other words, the length has been gradually reduced. Another illustration of this trend is the large steam generating unit in which the long and narrow boiler is gradually being shortened. A third illustration is that of the commercial boiler of the firebox type, the furnaces in which are generally short.

As concerns the time element, air velocities in the furnace determine the amount of time that the oil globules and air particles shall have for mixing and the trend in certain applications is toward increased velocities. In marine practice, for example, it is not unusual to carry air pressures of 3 to 10 in. of water in the furnace. Air pressures of such magnitude affect the time element considerably and the velocities employed become especially significant when cognizance is taken of the fact that marine furnaces generally have the shortest space for gas travel of any type of furnace. In industrial furnace practice, there have also been applications where more than 10 in. of water have been carried.

The furnace having all brickwork is rapidly disappearing and cold furnaces with a minimum of brickwork are coming into general use. In the case of the smaller sized domestic boiler the tendency is to expose more and more of the water-cooled shell. In the larger steam generating units, we find not only that the side walls are water cooled but also that the floor and roof of the furnace consist of exposed water tubes. All of this results in a more naked boiler and a minimum of brickwork. Thus the boiler of yesterday with its dutch oven, long brick arch, tile baffle and gas-choking bridgewall is clearly becoming a thing of the past and the boiler of today is depending less and less on brickwork for radiant heat to ignite and burn the fuel.

Even in the infrequent instances where brickwork is retained in modern installations, the tendency is away from dependence on the brickwork, where high burning rates are involved. This is because the temperature of the refractory is lowered as the boiler load or rating is reduced.

New Requirements in the Burning of Fuel Oil

Along with changes in boiler design, furnace design and construction, draft and air velocities, and the use of high burning rates, have come the requirements that combustion be completed in the least furnace space, in the shortest possible time, and with the least refractory surface. We can no longer wait for the atomized oil globule leaving the burner to burn slowly on its outside surface as it flows along in the air stream. Instead, fine, thorough and rapid mixing make it possible to reduce to a minimum the dependence on length of gas travel, on contact time for the air and oil, and on refractory. In an attempt to devise ways and means for correcting prevailing burner shortcomings[1] the author has found that all avenues of approach tended to converge on *mixing*.

FINE MIXING: By fine mixing is meant the breaking down of the coarse oil globules to the utmost fineness. This involves a greater degree of breakdown of the oil globules than can be obtained by the atomizer proper.

THOROUGH MIXING: This involves the dispersion of the oil globules forming the spray, and the dispersion of the vaporized and gasified oil near the burner, into the stream of air. This is quite a different procedure from that of waiting until each oil globule has the opportunity of mixing with the air particles in the process of flowing along the furnace.

FAST MIXING: By fast mixing we mean mixing that takes place at a great speed and close to the burner.

Utilization of this approach to the problem will involve more thorough mixing of the oil and air particles close to the burner and, as a result, the oil globules will not have to travel so far or take so much time in contacting the air particles. This, in turn, means that complete combustion will be speeded up. In brief, then, the theory of fine, thorough and fast mixing is based on the following:

1. Reduction of the oil globules to as near a gaseous state as possible, thereby increasing the fineness of mixing of the oil and air.
2. Increasing the thoroughness and speed of air and oil mixing at the burner so that a better combustible mixture can be had.
3. Decreasing dependence on space, time of burning, and temperature toward supporting ignition and combustion, as the combustible mixture improves. Once such a combustible mixture of fuel and air is ignited, it can be expected to keep on burning and to maintain a high enough temperature to vaporize and gasify the oil globules without very much assistance from refractory surface.

To apply this theory in such a way that the burning of oil becomes less dependent on space, time and refractory, some comparatively new practices are involved. Two of these are—smashing and dispersing the oil spray, oil globules, vapor and gases; and proper shaping, placing and concentration of the flame. Keeping these points in mind we can pass to a more detailed consideration of the steps involved in their effective application. These steps entail:

1. That the fuel oil be properly conditioned as to pressure and temperature and that it be properly atomized by a well-designed burner.
2. That the oil globules be vaporized and gasified in the shortest possible time; this to be accomplished by means of high flame concentration.
3. That the air as well as the fuel be heated in the process of passing through the refractory throat; this to be accomplished by proper air-block design and by proper shaping, placing and concentration of the flame. The heat of the flame must be concentrated in such a manner as to heat the incoming oil and air either directly or by heat which is reflected by a refractory throat; and such heat, whether from the flame or from the refractory throat, must be absorbed by the incoming oil and air before it is absorbed by the boiler or other heating surface.
4. That the oil globules be dispersed and mixed by a high air pressure drop through the fuel spray.
5. That the oil globules and air particles be induced to mix faster; this to be accomplished by having the air meet the oil spray at such an angle that will permit most effective mixing, as well as by the use of air vanes, of such design and position as will give the desired high turbulence.

Marine Installation Compared with Conventional Boiler

Even though this theory has not been applied completely, we find some aspects of it in marine practice. In the following illustrations a conventional boiler installation is compared with a marine installation laid down along the lines of this theory.

In the conventional boiler installation with a burner of approximately 350 gal per hr capacity, a flame travel varying between 15 and 30 ft, would be required to burn the oil globule from the outward surface inward to the liquid heart. The exact furnace length required would depend on the air pressure, the flame concentration, the air vanes, etc., but for the purpose of this illustration it may be taken as 20 ft with an average draft in the furnace of 0.05 in. of water. Such a draft is equivalent to a velocity of about 15 ft per sec. Thus the length of time required for the oil globule to be completely consumed would be 20 divided by 15, or $1^1/_3$ sec.

In the marine application under consideration it was found that by using forced draft of 18 in., with air blocks shaped to force the air at an effective angle to the oil spray, and use of a properly shaped flame concentrated close to the burner, it was possible to complete combustion in a furnace which is less than 7 ft. With a pressure inside the furnace that would produce a velocity of about 160 ft per sec, complete combustion of the oil globule could be had in 7 divided by 160, or approximately 0.044 sec.

This means that the length required for flame travel in the furnace was reduced to about one-third that of the first illustration, and that the time required for complete combustion of the oil was reduced one-thirtieth of the original figure.

[1] See "Correcting Burner Deficiencies," a book by the author which will be published shortly.

Turbulence and Combustion In Pulverized-Coal Furnaces*

By B. J. CROSS

Combustion Engineering Company, Inc.

Following an explanation and illustration of the distinction between laminar and turbulent flow, the author stresses the importance of turbulence in attaining complete combustion with pulverized coal and shows the principal burner arrangements employed. The relation between furnace pulsations and turbulence at different ratings is discussed.

THE term turbulence as applied to combustion in furnaces refers to a disturbed condition of the furnace atmosphere resulting in a mixing of the combustible and air which is conducive to more rapid and more nearly complete combustion. It is generally considered to be a necessary and desirable condition in furthering the combustion process. In the earlier pulverized-fuel installations before the development of water-cooled furnaces, pains were taken to avoid excessive turbulence in the furnace. Flames could not be permitted to brush the furnace walls, and secondary air was admitted at low velocity and in distributed ports in such a manner as to produce what were called "soft" flames that would not be destructive to the refractories. Combustion rates were kept low to avoid high furnace temperatures so that excessive slag would not be formed.

In completely water-cooled furnaces a high degree of turbulence is essential. The most active combustion is localized as near as possible to the burner zone, leaving to the after part of the furnace the function of continuance of the combustion to an economic degree of completion. To accomplish this localization of the active combustion zone, intensive turbulence is required. It is no longer necessary to favor the furnace walls and primary and secondary air at high velocities may be used. The high rate of combustion in the burner zone is possible because of the relatively high concentrations of the reactants, oxygen and fuel. They cannot, however, be made to combine any faster than they can be brought into contact and turbulence is necessary to produce mixing. As combustion proceeds, the furnace atmosphere becomes depleted of its oxygen and is diluted with the products of combustion. The last of the carbon must be burned in an atmosphere containing between two and three per cent oxygen A continued turbulence is, therefore, desirable to keep the loss due to unburned carbon within economic limits.

In a pulverized-coal furnace a primary turbulence is inherent in the streams of fuel and air. A secondary turbulence is produced by the impingement of or interaction between these streams. These terms, primary and secondary, apply to the order of incidence rather than to the order of importance. The mechanism of the production of these two types of turbulence is quite different.

Laminar and Turbulent Flow

In a fluid flowing in a pipe or duct the condition of flow at low velocities is termed viscous or laminar. In this condition the elements of flow are parallel. The velocity is highest at the center of the duct and grades off to zero in the stationary film at the periphery.

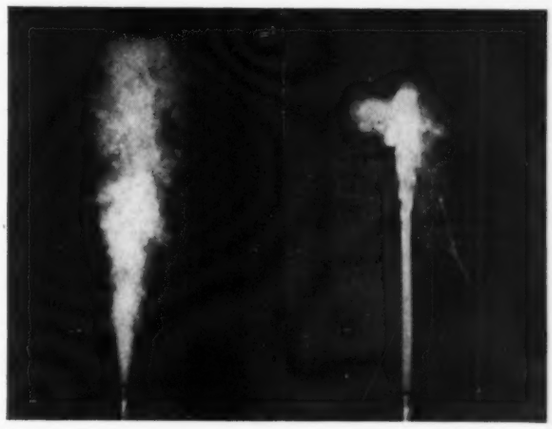

Fig. 1—Turbulent and Laminar Flow in Jets

The stream appears to be made up of concentric cylinders, one slipping upon another.

As the velocity is increased, the parallel elements of flow are broken up and the flow becomes turbulent. In such state of flow eddies and cross currents appear and the velocity of the stream becomes more nearly uniform across its section. At the periphery of the stream the stationary film is thinner and the velocity near the film is higher than for laminar flow.

In laminar jets, the stream changes but little in diameter as it issues from the orifice, see Fig. 1 (*right*). This is probably because of the fact that the flow elements at the periphery of the stream have a relatively low velocity compared to the average and the drag on atmosphere is

* Excerpts from paper presented at the Joint Meeting of the Coal Division of the American Institute of Mining and Metallurgical Engineers and the Fuels Division of The American Society of Mechanical Engineers, at Birmingham, Ala., Nov. 7–8, 1940.

correspondingly low. The discharge from a stack on a windless day shows this characteristic flow. Another example of a laminar flow is the smoke from an idle cigarette in a quiet room.

A marked characteristic of a turbulent jet is its expansion as it issues from the orifice, Fig. 1 (*left*). The boundary of the stream appears woolly and eddy formation can be plainly seen.

The expansion of the jet as it issues from the orifice is due in part to the slowing up of the velocity and in part to the velocity component at right angles to the direction of flow. This radial component of velocity gives the jet a fluttering characteristic which may actually produce a vibration. At sufficiently high velocities, an audible note may be produced. This fluttering of a jet may be demonstrated by means of streamers of light silk ribbon or thread held in its path. The action is similar to that of a flag, flying in a stiff breeze.

The eddying noticeable at the boundary of a turbulent jet causes a feathering off of the stream in small vortices which is helpful in securing ignition. A pronounced eddy will occur at the mouth of a blunt burner nozzle. This eddy may be accentuated by means of a restriction in the nozzle throat. These eddies serve as points of ignition. While the average velocity of the stream may be well above the velocity of flame propagation, the formation of these eddies results in boundary velocities much lower than the average. Otherwise the flame would be blown away from the burner and ignition would be unstable.

At the velocities occurring in furnaces laminar flow cannot occur. The jets of primary and secondary air are both in turbulent flow. Probably the nearest approach to what may be called laminar combustion is the candle flame. Incidentally, in the volume occupied by the visible flame, the combustion rate of a candle is somewhat over 2 million Btu per cu ft per hr. Such a high rate of combustion is possible, partly because of the large ratio of surface to mass and also because oxygen is supplied to this surface at relatively high concentrations. The highest temperature of a candle flame is near the surface where combustion is taking place. This high surface temperature induces convection currents that rise swiftly and wipe off the products of combustion and permit the contact of fresh air, richer in oxygen, with the combustible. The final combustion at the tip of the candle flame takes place in an atmosphere containing about 16 per cent oxygen. If the oxygen content at this

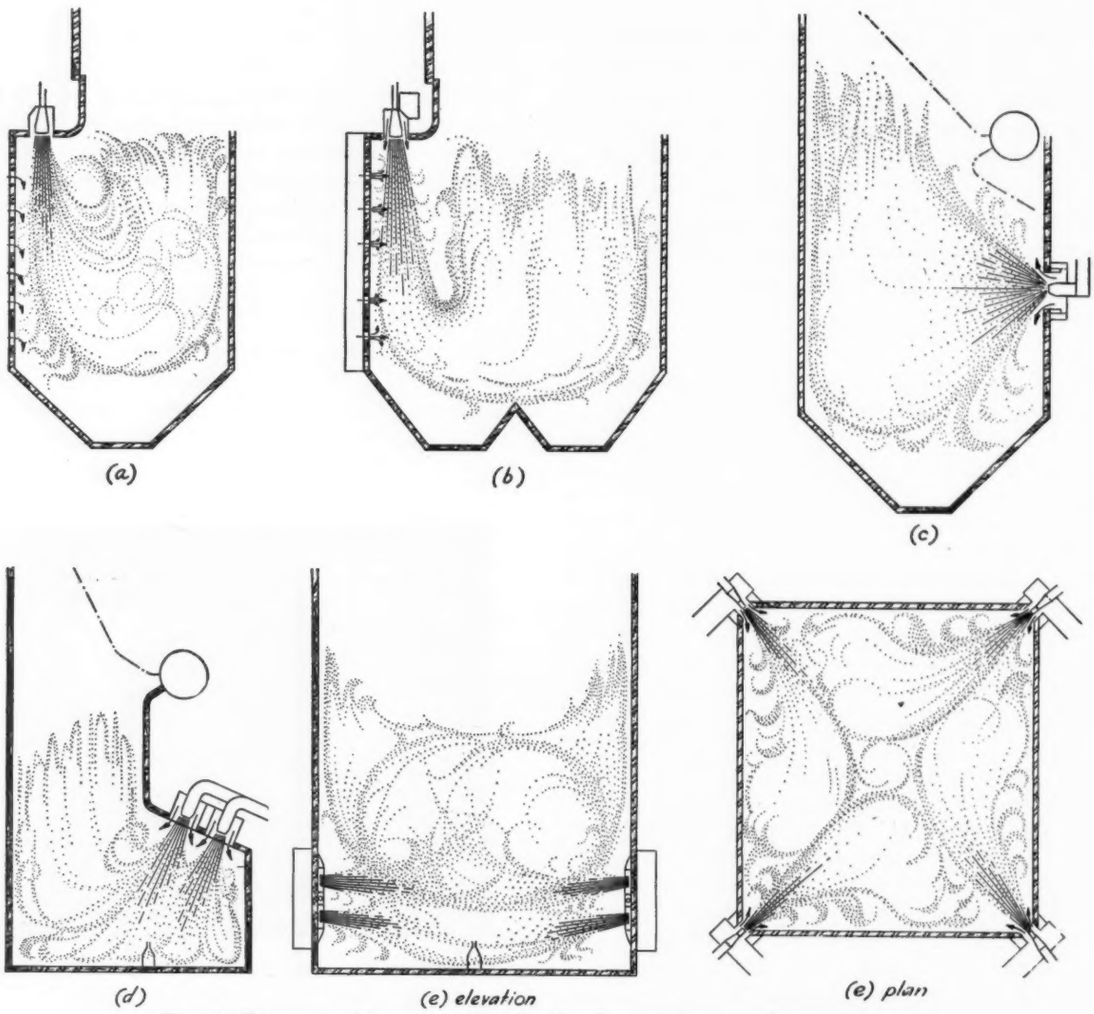

Fig. 2—Diagram of furnaces showing five burner types and arrangements

(*a* = Vertical, natural draft; *b* = Vertical, forced draft; *c* = Horizontal, "turbulent" type burner; *d* = "Impact" type burner; *e* = Corner-fired burner.)

point is reduced even to 14 per cent, combustion is incomplete and smoke results. With an atmosphere containing 4 per cent CO_2 (16 per cent O_2) supplied at the base of the flame, the candle will not burn.

Methods of Firing Pulverized-Coal Furnaces

Turbulence within a furnace is a result of the inherent turbulence of the jets, the impingement of the jets upon each other and the turning and eddying due to the confinement of the jets by the furnace walls.

Air for combustion is introduced into the furnace as primary air which carries the fuel, and as secondary air, the remainder of that required. The function of the primary air is to introduce the fuel so that ignition is prompt and stable and to distribute the fuel so that all parts of the furnace may be utilized in combustion.

Secondary air is introduced into the furnace at or near the burners in a manner designed to promote speedy mixing with the burning fuel of the primary air stream.

Relatively high pressure is provided for the primary air, ranging from 6 to 15 in. water gage, depending upon the method of firing. Secondary air, which is the larger quantity, is supplied usually at somewhat lower pressure, principally as a matter of economy.

Fig. 2 shows diagrams of various methods of firing for pulverized-coal furnaces. The early installations of pulverized coal operated with secondary air supplied with natural draft. In natural-draft furnaces, Fig. 2-*a* the chief source of turbulence was the primary air jets. Vertical firing was the rule and a long path was provided for the flame. Secondary air, induced by furnace draft entered at low velocity in ports distributed along the path of the flame. A larger number of small burners is more effective in producing turbulence than fewer large burners. For this reason the storage system is best adapted to this method of firing, as increasing the number of burners involves only the relative small expense of additional feeders. In direct-fired systems, economy dictates the use of as large mills as possible and the division of the mill stream to a large number of burners is not very practical.

A logical development of the natural draft method of firing was the addition of forced draft, Fig. 2-*b*. Secondary air is introduced in smaller high-velocity jets. In order to break up the primary air streams quickly, the admission of secondary air is closer to the coal-burner nozzles. Water cooling of the front and side walls permitted the higher combustion rates engendered by the greater degree of turbulence obtained. While this system has been used with direct firing in both large and small units, the advantage of the storage system also applied to this method of firing. Furnaces of this type are often fired from two sides and as many as twenty burners have been used. In completely water-cooled furnaces, combustion rates as high as any in modern practice have been obtained.

The next development in firing method was based on the discovery of the turbulence which already existed and the "turbulent" burner, Fig. 2-*c*, was devised. This burner fires horizontally and all of the air used for combustion is introduced through the burner opening.

In order to distribute the coal across the furnace, the primary streams are given a whirl within the burner nozzle either by providing a fan scroll entrance to the burner or by placing propeller-like spinners in the burner mouth. The secondary air is also given a spin by controllable tangential vanes at the inlet to the burner throat.

The whirling of the primary air stream in addition to effecting distribution of coal also provides a large surface to the jet for contact with the secondary air. The control of spin of the secondary air permits it to be regulated so that it does not strike the primary air stream forcibly until ignition is well established. The shape of the flame can also be controlled by the secondary air vanes.

Horizontal turbulent burners are well adapted to direct firing as they may be of large capacity and few in number. Usually two or four burners are used, although in installations of small capacity, single burners have been successful. In storage system installations as many as eight burners have been used.

Fig. 2-*d* represents what might be called an impact burner. This type of burner is used exclusively with slagging bottom furnaces. The burners are usually set in an arch located low in the furnace or sometimes in side walls and inclined downward toward the furnace bottom. High velocities of both primary and secondary air are used and these streams impinge on the furnace hearth. A high degree of turbulence is obtained resulting in the high local temperatures necessary for slagging.

Fig. 2-*e* represents a corner-fired furnace. In the corner- or tangentially-fired furnaces, although both the primary and secondary jets are in a high degree of turbulence, mixing is due in greater part to the interaction of these jets. Obviously, a minimum of four burners is necessary for this type of firing. Two burners to a corner give greater flexibility in load and three and four burners per corner have been used. The burners are usually directed to a 6- or 8-ft tangent circle. On recent installations the burners are adjustable so that the tangent circle may be changed while the furnace is in service.

The distance from the burner mouth to the tangent circle is short and the jets impinge at high velocity. The cyclonic action set up by the burners causes, in the rectangular furnace, a series of eddies, so that the cross-section of the furnace is completely filled with the burning mixture. The cyclonic disturbance persists to some degree to the furnace outlet and is effective in completing the combustion of the coke particles. The gases rise spirally in the furnace and the direction of flow is being constantly changed. The carbon particles which are very dense compared to the gases tend to move in straight lines. Their position relative to the gas stream is, therefore, constantly changing.

A high degree of turbulence is possible with the tangential system of firing. It is applicable to both slagging and dry-bottom furnaces.

Effectiveness of Turbulence in Obtaining Complete Combustion

The effectiveness of turbulence in the furnace may be measured by the amount of unburned carbon in the ash leaving the furnace. As the cost of supplying air to the furnace increases with the velocity imparted to it, there must be an economic limit to the pressures used. In this, the law of diminishing returns applies and the economic limit may be established empirically.

In Fig. 3 the percentage of combustible in the ash

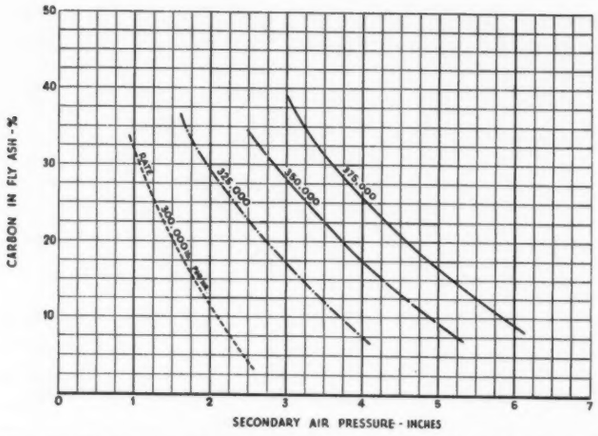

Fig. 3—Variation of combustible in ash with secondary air pressure—test results

leaving the furnace is plotted against the pressure of the secondary air for different rates of output. There is a definite reduction in the carbon loss as the secondary air pressure is increased. The excess air was held constant during this series of tests. These tests were made on a furnace fired with horizontal burners. The pressure of the secondary air was regulated by the vane opening.

In Fig. 4 the carbon in the ash is plotted against excess air at constant rating. During this series, the secondary air pressure was held practically constant.

Carbon losses may also be reduced by increasing the amount of excess air. This means increased power for both the forced- and the induced-draft fans. There is also some sacrifice in efficiency. Fig. 4 shows approximately the same reduction in combustible in the fly-ash by reducing the CO_2 from 17 to 15 per cent as was obtained by increasing the secondary air pressure from 1 to $2^1/_2$ in. A reduction of CO_2 from 17 to 15 per cent corresponds to increasing the excess air from 10 to 25 per cent.

In Fig. 5 are shown selected data of a series of tests made on a tangentially fired furnace. Secondary air pressure, excess air and carbon loss in the flue dust are plotted against rating of the boiler. The feature of this graph is the carbon loss which makes practically a flat curve with increasing rating and decreasing air supply. The explanation may be in the increasing secondary air pressure which increases the degree of furnace turbulence.

Furnace Pulsations Probably Associated with Vibrations Due to Turbulence

The chart sections which appear on this graph are parts of a record of furnace draft which were taken with a sensitive gage using a high-speed clock. This gage indicated a rapid pulsing of the furnace atmosphere which is believed to be associated with furnace turbulence. The frequency is from 4 to 6 cycles per second, and, as may be seen, the amplitude increases with rating. The individual pulses are too high in frequency to register on a U-tube or inclined draft gage. The gage used was of the diaphragm type and had no orifices or other damping devices. The moving parts of these diaphragm gages have inertia and also their own period of oscillation so it is not likely that the graphs are a true record of the furnace vibration. It is, however, believed that the indications are relative and present a comparison between two furnaces or for the same furnace under different conditions.

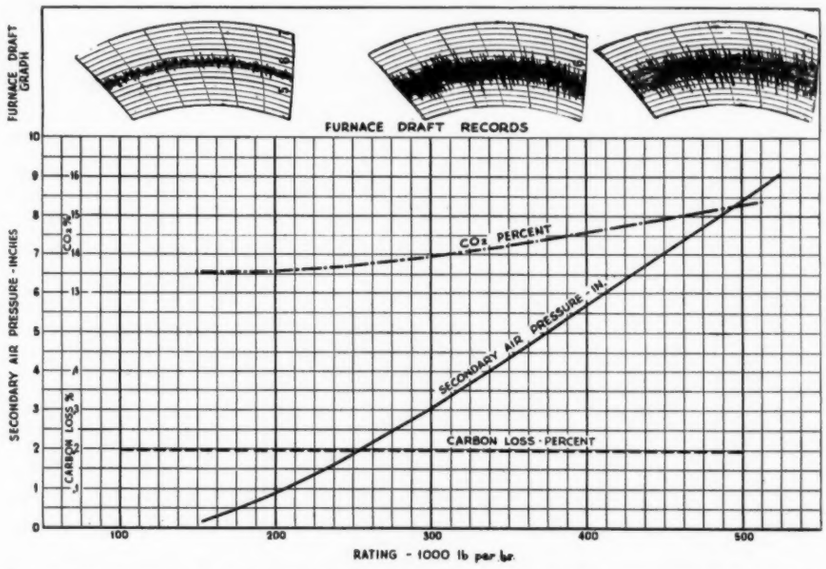
FURNACE DRAFT GRAPH
FURNACE DRAFT RECORDS
SECONDARY AIR PRESSURE - INCHES
CO₂ PERCENT
SECONDARY AIR PRESSURE - IN.
CARBON LOSS - PERCENT
RATING - 1000 lb per hr.

Fig. 5—Variation of combustible of ash and secondary air pressure with rating. Furnace draft graphs—test results

No explanation of these graphs is offered nor is any claim made except that they are believed to be associated with vibrations resulting from turbulence. The furnace graphs are fairly constant in frequency and increase in amplitude with the rate of firing. Primary-air density and velocity and secondary-air velocity also increase with rating and the vibration graphs for these streams show an increasing amplitude with rating. It is quite possible that this method is or may be developed to be a measure of at least relative furnace turbulence in burning pulverized coal.

While this paper has been limited to turbulence in pulverized-coal-fired furnaces the considerations will apply with but little modification to gas- and oil-fired furnaces.

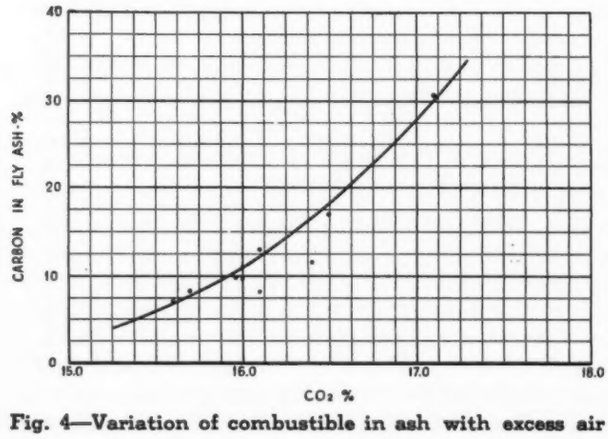

Fig. 4—Variation of combustible in ash with excess air

REVIEW OF NEW BOOKS

Any of the books reviewed on this page may be secured from Combustion Publishing Company, Inc., 200 Madison Ave., New York

An Introduction to the Kinetic Theory of Gases

By Sir James Jeans

This well-known physicist, whose writings have offered a simple explanation of many intricate scientific phenomena in language understandable to the layman, has brought out the present volume dealing with the kinetic theory of gases for the average student of physics and physical chemistry. It embodies much of the scope covered by the author's earlier work on "Dynamical Theory of Gases," but in a simpler manner, and mathematical proofs have been subordinated to physical treatment. It should be helpful to and readily understood by anyone who possesses a foundation in thermodynamics.

The book contains 311 pages and is priced at $3.50.

Pumps

By Frank A. Kristal and F. A. Annett

The authors make available herein a comprehensive presentation on types and designs of pumps and the applications for which they are suited. Boiler-feed, deep-well, sump and sewage pumps have been treated in separate chapters. A sufficient amount of space has been devoted to service limitations and performance of the various types of pumps. Installation, operation and supervision as well as pump troubles and their remedies, have been covered extensively.

Unlike many other pump books which primarily consider problems in design and hydraulic theory, this book was compiled essentially for the user as an aid in the selection of pumps, and covering a wide range of applications.

There are 339 pages, 6 × 9. The price is $3.50.

Boiler House and Power Station Chemistry

By Wilfred Francis

With the purpose of informing chemists, boiler-house operators and students of the fundamental chemical considerations involved in fuel burning and the generation of steam and electricity, this British author has divided his book into two main parts. Part one discusses general chemical aspects of the combustion of coal and the industrial chemistry of water and oil. It is simply written to be generally intelligible to those with no great knowledge of chemistry. Part two describes analytical methods undertaken in normal power station practice and, of necessity, is more technical.

There are 203 pages, $5^1/_2 \times 8^1/_2$. The price is $4.50.

Practical Mathematics

By G. M. Hobbs, J. McKinney and J. R. Dalzell

This, the second edition, is devoted to the phases of mathematics most widely used in trade and in applied branches of engineering. It is intended for beginners and for those who wish to brush up on long-forgotten fundamentals with a minimum of time and effort.

The book covers addition, subtraction, multiplication and division as well as fractions, decimals, percentage, factoring, powers, roots, ratio and proportion, equations, formulas, graphs and logarithms. Illustrative problems, which are worked out and explained in detail, are practical ones such as would be encountered in the different branches of engineering. By the study of such problems the student learns mathematics as well as its application to the fields of business.

Supplementing the mathematical considerations there are many tables including weights and measures and numerous suggested problems and examination questions with the answers.

The book contains 599 pages, $5^1/_2$ x $8^1/_2$, and is priced at $2.40.

Transactions A.I.M.E., Vol. 139, Coal Division, 1940

The 1940 volume of A.I.M.E. Transactions of the Coal Division contains papers and discussions presented before the Division at meetings held in Chicago, October 13 to 15, 1938; New York, February 13 to 16, 1939; Columbus, October 5 to 7, 1939; and New York, February 12 to 15, 1940. The problems considered include sampling, influence of mechanization on coal production, shaker-conveyor mining of anthracite, trends in rock dusting to prevent dust explosions in mines, factory testing of propeller mine fans, safety practices, ground movement and subsidence studies, collapsible steel props in longwall anthracite mining, concrete and steel roof support in anthracite mines, economics of wood preservation in coal mining, longwalling on timber in Alabama coal mines, effects of artificial support on longwall mining. Among other subjects considered are photoelasticity and mine-pillar and tunnel problems, launder and table washing of fine coal, flocculation and clarification of slimes, pressures developed during the carbonization of coal, low-temperature coke by the Disco process, proportions of free fusible material in coal ash and pulverized coal as a fuel for open-hearth furnaces.

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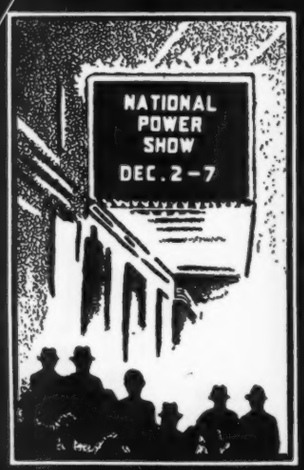

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STEAM ENGINEERING ABROAD

As reported in the foreign technical press

Powers of British Electricity Board Broadened

As reported in *Engineering* (London) of October 11, the Central Electricity Board has been given authority, under the Emergency Defense Order, to generate electricity itself and to provide and operate generating stations.

Under the Electricity Supply Act of 1926 the owner of a selected station who fails to carry out the directions of the Board regarding its operation or extension may be deprived of his ownership. The station may then be acquired by some other authorized undertaking or, as a last resort, by the Board. Similarly, although primarily the Board is required to make arrangements with existing central station companies for the provision of new stations, it can be authorized by the Electricity Commission to build new stations itself. In effect, these powers have not been heretofore exercised as no occasion has arisen to warrant such action. However, the new position apparently is that the Board, with the consent of the Electricity Commissioners, can now build its own stations irrespective of the selected station owners, but must still try to arrange with other undertakings to operate them on reasonable terms before proceeding to do so itself. This modification appears to be linked up with the announcement that new stations are to be built in Southeast England, Southwest England and South Wales, respectively. These are to be relatively small stations, the first being laid out for 50,000 kw capacity and each of the other two for 30,000 kw. Thus it appears that they are to be regarded as emergency plants.

Old Boiler Used as an Accumulator

An interesting application of the principle of steam storage to accommodate boiler loading to the variable steam demands of a British dye works is described by W. Goldstein in the October issue of *The Steam Engineer*. Here were installed two boilers of the Lancashire type, the larger and newer of which is stoker fired, supplying steam at 160 lb, 500 F, and the smaller furnishing steam at 120 lb. The latter was ordinarily held in reserve. The greater part of the steam was supplied to a 500-hp condensing engine, some live steam was furnished through a reducing valve to process at 80 lb and the remainder to the dye house at 40 lb. The dye-house demand fluctuated rapidly and between wide limits with the result that boiler pressure dropped at times to as low as 100 lb and with a sudden drop in demand often rose to the point at which the safety valves began to blow. This condition had a very unfavorable effect on the steam engine as well as on the plant operation and economy.

To remedy the situation the standby boiler was converted into a steam accumulator by equipping it with a charging device. The newer boiler continues to supply the steam engine as well as the 80-lb steam to process, but all of the steam required by the dye house and for plant heating is now taken from the accumulator. The arrangement is as shown in the accompanying sketch.

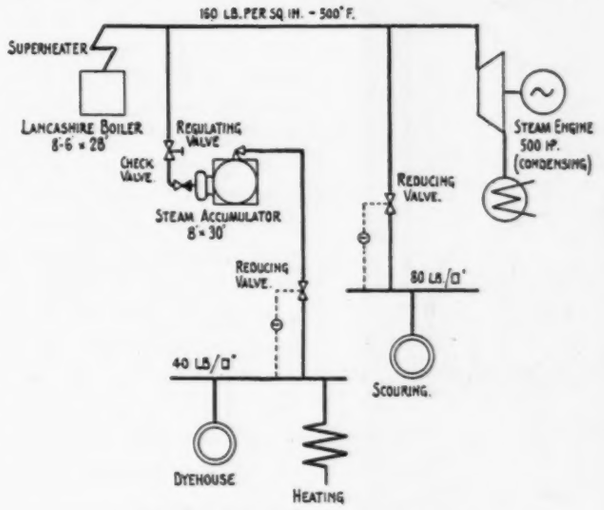

Diagram of present connections

After several months' operation it is reported that there is now no difficulty in maintaining the boiler pressure at 160 lb while that in the accumulator fluctuates between 135 and 60 lb.

Status of German Boiler Construction

Die Wärme of September 21, 1940, reviews the advances and the present state of boiler construction in Germany.

The demand for increasing pressures and temperatures which prevailed up to a short time ago seems to have ceased as it was found that the higher steam conditions introduced difficulties which began to appear at between 100 atmospheres (1420 lb per sq in.) and 120 atmospheres (1700 lb per sq in.). These difficulties lay partly in materials and partly in operation. Consequently, new power plants, designed or built within the past year, have employed a maximum of 80 atmospheres (1140 lb per sq in.) and 932 F total steam temperature. Such steam conditions yield good efficiency and do not necessitate reheating.

However, feedwater temperatures continue to increase and the later installations employ 350 to 390 F.

A definite increase in boiler unit capacity is noted, although not approaching sizes that are common in the

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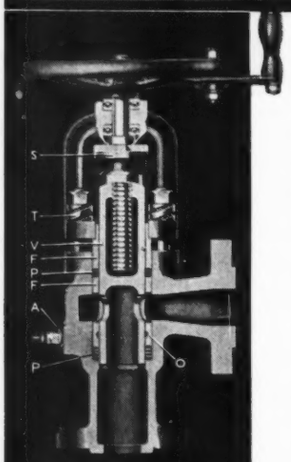

Yarway Seatless Blow-off Valve. Operation: After Valve is closed, shoulder S on plunger V contacts with upper follower gland F, forcing it down into body and compressing packing P above and below port. Annular groove O connects with Alemite fitting A for lubricating plunger and packing. Yoke springs T maintain continuous pressure through follower gland F on packing rings P.

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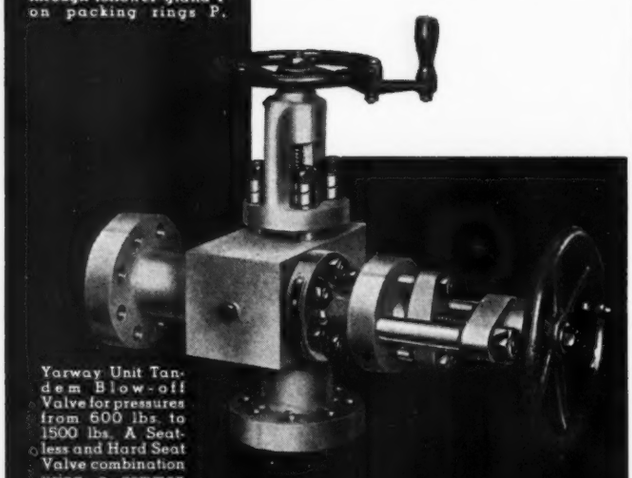

Yarway Unit Tandem Blow-off Valve for pressures from 600 lbs. to 1500 lbs. A Seatless and Hard Seat Valve combination using a common forged steel body.

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BLOW-OFF VALVES

United States. Early in 1939 a unit of 275,000 lb per hr was under construction, to be followed later in the year by one of 330,000 lb per hr, whereas during 1940 several units of 440,000 lb per hr were ordered.

According to *Die Wärme*, one of the greatest difficulties formerly experienced by the Germans in building such large boilers was in fabricating the drums. To offset this limitation the boilers were made as narrow as possible. However, recent equipment for rolling the heavy plate in large sizes now makes it possible to build units up to 880,000 lb per hr.

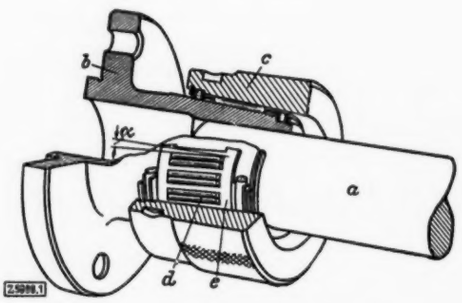
Direct firing of pulverized coal is now common, and the mills have been improved so as to deliver the required degree of fineness for high combustion rates. Furnace heat releases have risen in some cases to as high as 33,700 Btu per cu ft per hr. For such high rates, however, one must consider the relation of fineness of grinding and the arrangement of radiant heating surface.

It is noted further that while orders for the once-through type of boiler have decreased since 1938, with respect to the total boiler orders, other forced circulation boilers continue in popularity.

A Roll-Type Coupling

One of the oldest forms of connection for a shaft is that of a plug and hole, but to transmit power through such a connection requires either a key or pressed fit. The former offers the disadvantage of making it difficult to center the parts accurately and also tends to weaken the cross-section with respect to resistance to fatigue, whereas the latter is difficult to loosen.

A roll coupling, described in *VDI Zeitschrift*, vol. 84, No. 11, was devised as a means of avoiding these shortcomings. Referring to the sketch, *a* and *b*, the parts to



Cut-away section of roller coupling

be connected, seat along straight cylindrical surfaces and are surrounded by the ring *c*. This ring and the extension of *b* are tapered and between these tapered surfaces are cylindrical rollers, *d*. The rollers are guided by a cage, *e*, in such a way that their axes are at an angle, α with the axis of the shaft. Operation is as follows:

By turning ring *c* clockwise it will be caused to move toward the left along the shaft due to the angularly guided rollers, and the taper causes the extension of *b* to grip the shaft *a*. There is only one rolling friction to be overcome, the friction coefficient of which is about $^1/_{1000}$. As a consequence very high pressures may be realized between the rollers and the tapered surfaces.

By turning ring *c* counter-clockwise the coupling is readily loosened. In other words, this coupling is essentially a pressed fit that can be loosened.

The rollers are made of special high-strength steel, hardened, lapped and finished to ±1 micron. The transmitted force does not pass through the rollers but, instead, passes directly from *a* to *b*, and the stresses in both the ring *c* and the rollers remain unchanged with changing load.

Vibration is said not to loosen the coupling and it is claimed to possess a centering accuracy not attained by other connections that can be readily loosened. It has wide application to tools and power drives.

Increased Power Consumption in South Africa

According to the Annual Report of the Electricity Supply Commission of South Africa, recently published, the generating capacity of the system is 954,156 kw of which 171,926 kw was added in 1939. The output for last year was over $3^1/_2$ billion kilowatt-hours which represented an increase of 19.7 per cent. The annual consumption per customer was 1598 kwh. The well-known Klip generating station has now been brought up to nearly its contemplated capacity and construction on the new Vaal Station has been commenced.

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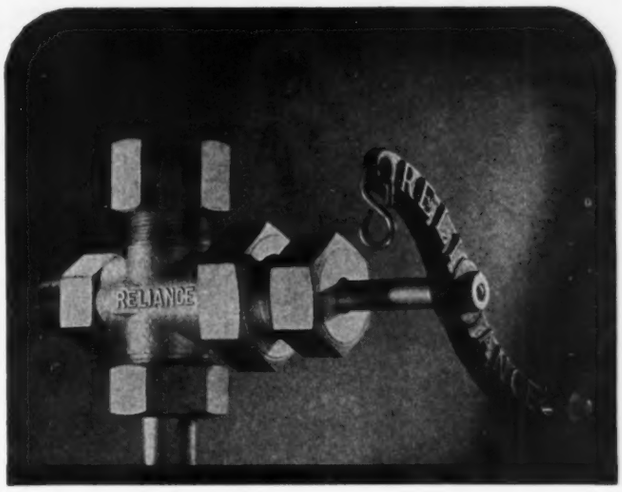

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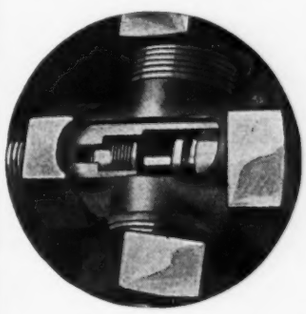

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NEW CATALOGS AND BULLETINS

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Boiler Control for Marine Service

The problem of securing efficiency, economy and reliability in the operation of marine boilers is dealt with in detail in a new bulletin No. 108 "Bailey Boiler Control for Marine Service" just issued by Bailey Meter Company.

This bulletin divides boiler control into the problems of combustion control, feedwater control and superheated steam-temperature control. It points out that the proper application and use of these control systems insures (1) maximum fuel economy, (2) elimination of smoke, (3) reduction of boiler and furnace maintenance, (4) safe operation of boilers and turbines, (5) increased boiler capacity. Performance results taken from the experience of users of such control of ocean-going steamers are cited to show the specific benefits derived by use of boiler control.

Detailed diagrams illustrating the arrangement and operation of the various control systems are shown together with illustrations of control units and installation photos showing their application aboard ship.

Boiler-Water Conditioning

"The Inside Story of Boiler-Water Conditioning" is a new edition of a 16-page treatise which has been published by Elgin Softener Corporation. It explains the wide variations in boiler feedwaters and operating conditions; tells how impurities accumulate inside a boiler and how they can be eliminated; explains the four essentials of boiler-water conditioning; and tells how to maintain ideal boiler-water conditions inside a boiler by using the correct treating and conditioning system for the particular job at hand. It is reported to tell how to eliminate boiler scale, sludge, foaming, wet steam, corrosion and wasteful blowdown—how to keep boilers clean—how to produce clean-dry steam.

Chemical Recovery

A new eight-page bulletin describing the C-E Chemical Recovery Unit has just been published by Combustion Engineering Company. It contains performance and installation data, test data, production record of a four months period, flow chart and it is profusely illustrated. This chemical recovery unit of the spray type is designed to recover the chemicals in sulphate mills and to generate steam.

Controlling Liquid Level

Liquid level controllers find wide adaptation to services in the power and process fields. They control levels and regulate the flow of liquids to or from surge tanks, storage tanks, stills, receivers, absorber towers, heaters, condensers and evaporator units. Five different methods of such control are described in publication No. 2939, recently issued by the Cochrane Corporation.

Complete descriptions of the operation and advantages of each type simplify proper selection from tabulated data that includes operating characteristics and list prices.

Corrosion and Scale Elimination

Hall Laboratories, Inc., present a 17-page booklet containing case histories taken from their files. The purpose is to bring to the reader's attention the various contributing factors to the formation of scale, the cause of embrittlement and the remedies for these troubles. These histories are written in a clear and straight foreward manner, without embellishment; and provide an insight to the various water problems existing in representative plants throughout the country.

Dry Chemical Feeder

The four profusely illustrated pages of Bulletin No. 2345 describe Permutit's new oscillating type Dry Chemical Feeder. A curved feed plate oscillates beneath the mouth of the hopper spout and discharges chemicals to a mixing tank proportional to the rate of water flowing. The rate of feeding may be adjusted even while the feed is in operation. Provision has been made to agitate the chemicals in the hopper and thus prevent "arching." The operating mechanism is doubly enclosed for dust-proof service.

Dust Collectors

Catalog No. 108 describing the Thermix Tubular Dust Collector has recently been issued by Prat-Daniel Corporation. The eight attractively illustrated pages describe a new principle of centrifugal collection, the practical advantages, construction details and typical layouts. There is also a list of some of the users and description of other types of Thermix Dust Collectors.

Steam, Air and Water Equipment

"Steam, Air and Water Equipment" is the title of a new composite catalog which has just been published by the Johnson Corporation. It contains more than 80 pages and is bound in convenient loose-leaf style. The first section covers the Johnson rotary pressure joint, a packless, self-oiling, self-adjusting, self-aligning joint for admitting steam or liquids under pressure into rotating rolls. The second section tells about the Johnson pressure equalizing pump, the boiler-feed pump that sidesteps the task of pumping against boiler pressure. The next section describes the "Electrap," an electrically-operated return trap for which is claimed greater reliability and more storage space because there are no complicated floats or levers. The boiler-water level control, is described in the fourth section, and the last section is devoted to the air and steam separators, oil absorbers and aftercoolers.

Multi-Point Indicator

For indicating drafts, pressures, differentials and other factors in boiler and industrial furnace operation, a new Republic multi-point indicator has been placed on the market. Zero adjustments and all piping connections for each gage unit are accessible from the front of the panel and each unit is designed to be withdrawn, like a book from a shelf, without disturbing other units. Each gage is actuated by a sensitive dry-bellows type of diaphragm for ranges from 0 to 50 in. of water or by a helical element for pressures above 50 in. of water. The gages have 12-in. vertical, translucent, rear-illuminated scales. The new indicator is supplied with from 2 to 16 of these compact, interchangeable gage units, and is built for either flush or projected mounting. It is described in detail in Bulletin No. 801 issued by Republic Flow Meters Co.

New Gasket Handbook

The Goetze Gasket & Packing Company, Inc., announces a new 64-page handbook and catalog on industrial gaskets. The company states that, due to great strides made during the past few years in engineering research, design, manufacture and application of gaskets, many former practices and products have been outmoded. This catalog No. 53 obsoletes all previous literature of the company. It contains advanced engineering data, developed in the Goetze research laboratory, shows many new and improved products, and gives complete size and price information. Profusely illustrated and concisely written, it offers a valuable time-saving reference.

Thermocouples

A 40-page catalog, N-33A (6) described as the first complete publication on thermocouples issued by Leeds & Northrup Company, lists a comprehensive line of assemblies with their parts and accessories, and includes information of general usefulness on the correct choice of couples. Tabulated in easy-to-use form, this information should be helpful to users as a guide to the best choice of couple for the application at hand. Illustrations and listings are so arranged that parts and accessories, as well as complete assemblies, are easily identified.